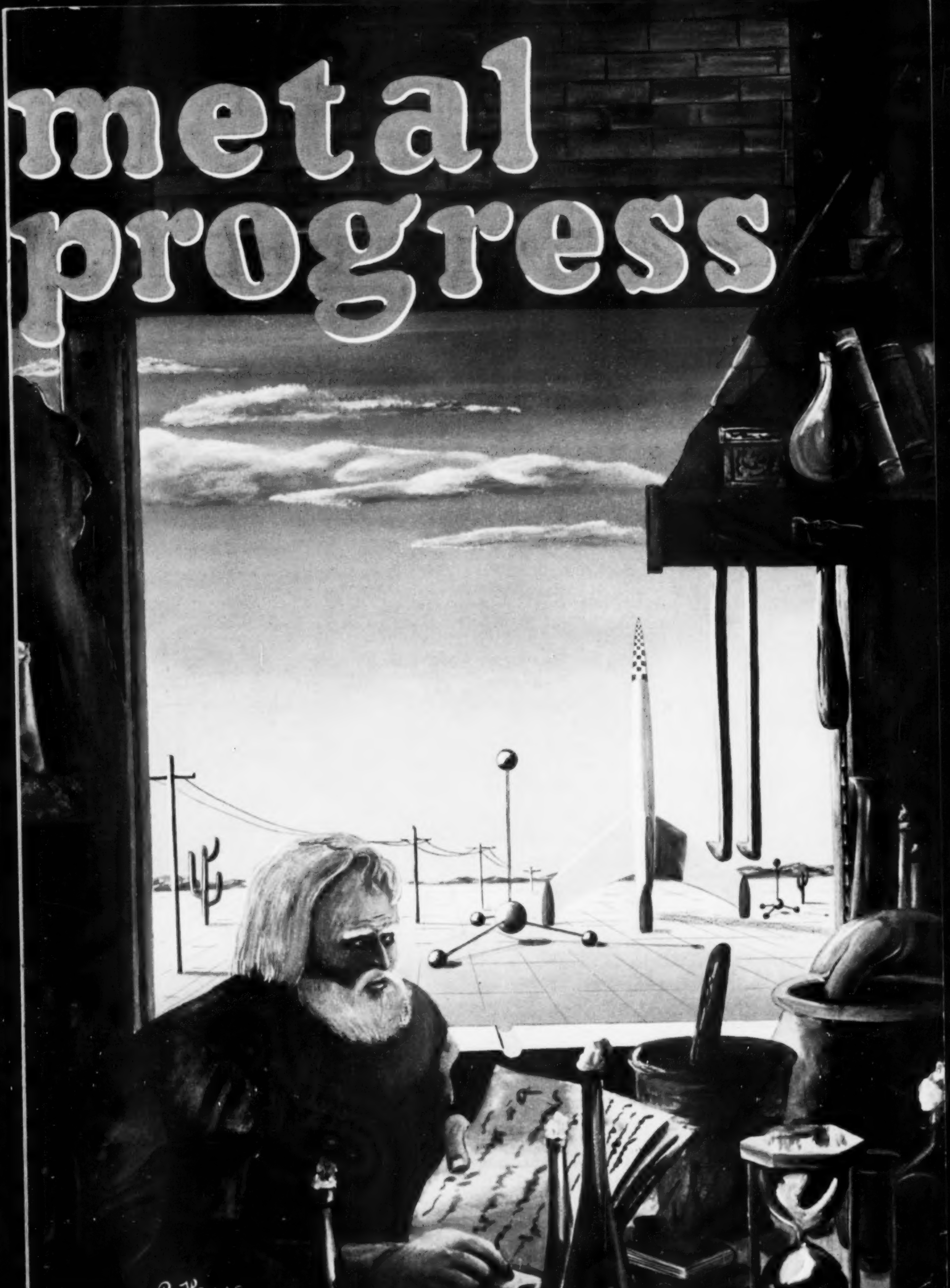
metal
progress
R. Haas

IN THIS ISSUE

The alchemist on the front cover searching for the "Philosopher's Stone" has his modern counterpart in the engineer searching for the ideal high-temperature material (see page 96). Cover design is by Ralph Haase, student at Cleveland Institute of Art.

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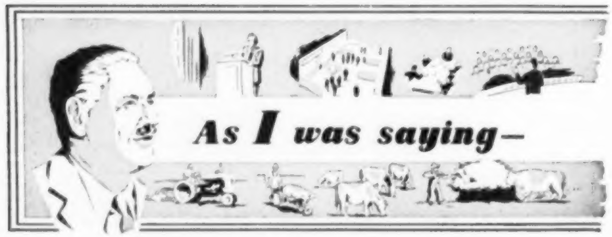


WHEN YOU READ THIS the big Metal Show & Congress will be events in the past, but as I write this it's still two weeks before the doors fly open, and that fact leaves me high and dry as far as actual reporting is concerned. But I just feel like predicting a thing or two about these events, and then when M.P. comes out the first week in November I'll read this column again and see how close I have come. So here goes with a crystal-gazing report on the 35th National Metal Congress and Exposition:

It was the largest convention in the history of A.S.M. More members attended than ever before.

The 211 papers all about metals were well delivered and well received.

The A.S.M. Seminar was again at the top with Prof. Alan Cottrell, the A.S.M. visiting lecturer from England, shining in the spotlight.

Don Clark of Cal. Tech. gave the Campbell Memorial Lecture in true California style.

Free coffee period—another A.S.M. service for the members—was relaxing and relieving.

The banquet was a sellout, the medalists were acclaimed, the speaker dynamic, the food excellent.

About 75 ladies enjoyed the luncheons, trips, theater and card party. The highlight was the luncheon-canasta party at A.S.M.'s National Headquarters (one of Cleveland's finest old Euclid Avenue mansions).

And how they rolled into the educational lectures and appreciated the fine work of the speakers—and the four o'clock coffee break just fitted into the close schedule.

The Metal Show "Dorm" at the Auditorium was an ace in the hole and the 100 members and guests who made use of it had clean sheets and a good sleep and, what's more, it didn't cost 'em a . . . cent.

Young Engineers' Day on Friday was a humdinger—some 1500 faculty and students came from engineering schools within 150 miles of Cleveland. Special trains from Columbus and Pittsburgh with buses from the other spots poured these eager-beaver engineers into the Exposition. It gave them an insight into the metals field such as they could secure in no other way. Since 50% of *all* engineering graduates find their life's work in the metal industry, the "Engineering Society of the Metals Industry" feels a responsibility to acquaint young engineers with prospects in the metals line. Consequently, the A.S.M. gladly picked up the tab for the complimentary luncheon and transportation costs of these coming young engineers.

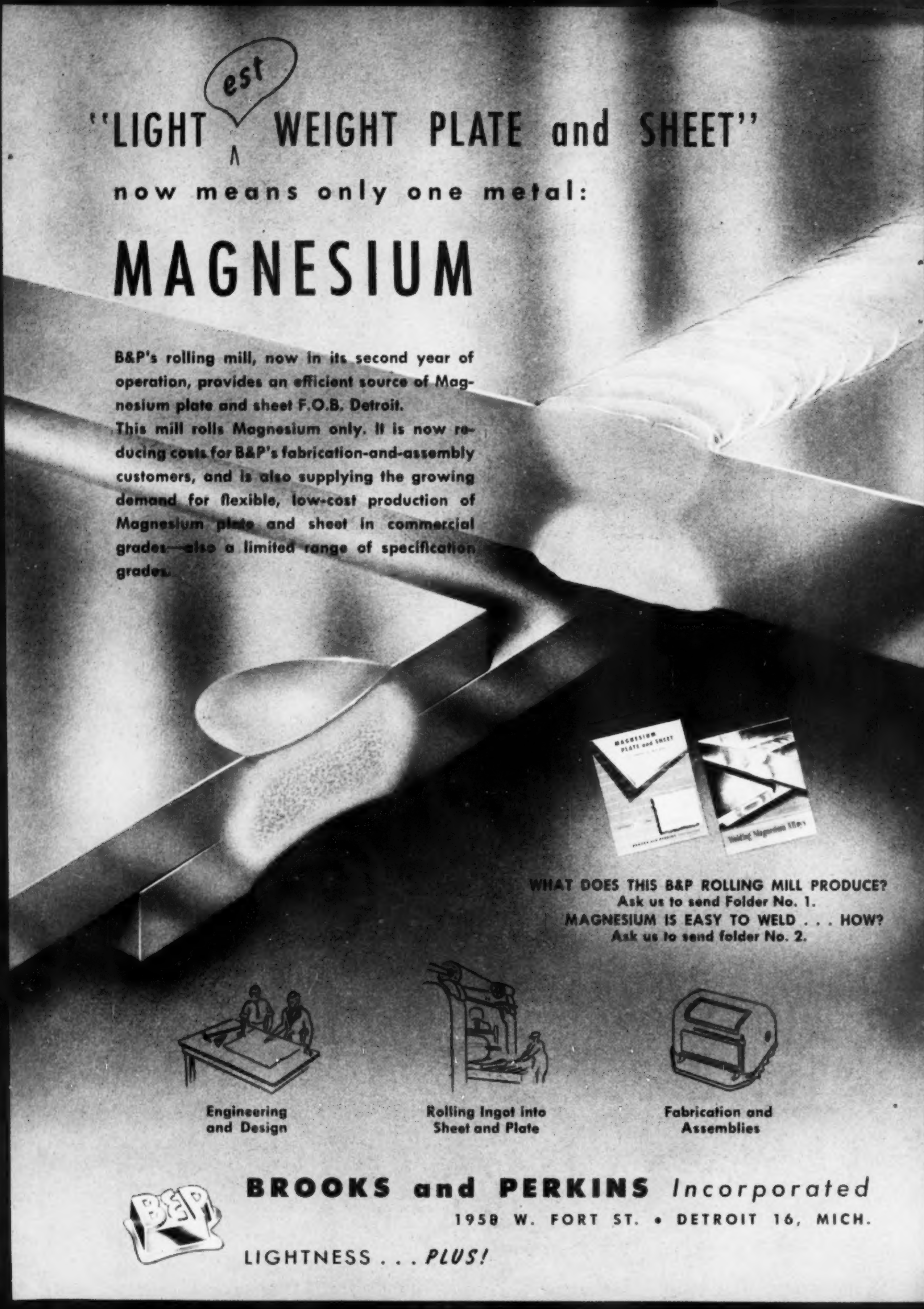
I could go on indefinitely pulling this and that out of my thoughts—events that have not yet happened. I can only make these bold forecasts because I know the careful and conscientious attention to plans and details that the fine staff here at A.S.M. has given during the past year. This one fact is known to all of us—if the plans and details are not worked out and firmed by the opening day of the Convention—then it's too late.

Too late? May it never happen to you or to us.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS


"LIGHT est WEIGHT PLATE and SHEET"
now means only one metal:
MAGNESIUM
B&P's rolling mill, now in its second year of operation, provides an efficient source of Magnesium plate and sheet F.O.B. Detroit.
This mill rolls Magnesium only. It is now reducing costs for B&P's fabrication-and-assembly customers, and is also supplying the growing demand for flexible, low-cost production of Magnesium plate and sheet in commercial grades—also a limited range of specification grades.
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Ask us to send Folder No. 1.
MAGNESIUM IS EASY TO WELD . . . HOW?
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BROOKS and PERKINS Incorporated
1958 W. FORT ST. • DETROIT 16, MICH.
LIGHTNESS . . . PLUS!

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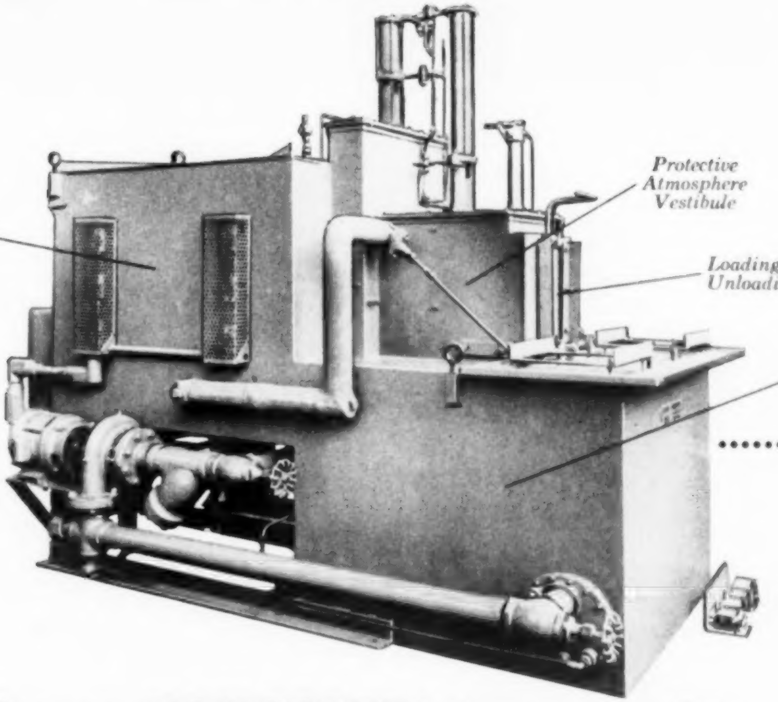


A new HOMOCARB® furnace with

protected quench

Now, for the first time, work can be direct-quenched from a Homocarb furnace under a protective atmosphere.

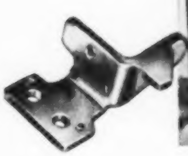
This new horizontal Homocarb combines the well known benefits of the Homocarb method . . . continuous, automatic control of time, temperature and atmosphere . . . with a protected quench. Work moves directly from the furnace to the quench under a protective atmosphere . . . without exposure to air.

Heat treaters, metallurgists and production men will quickly recognize that this new L&N Homocarb furnace—complete with Microcarb® atmosphere control—marks a significant step forward.

The complete equipment consists of:

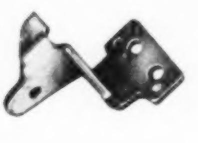
1. *The new horizontal Homocarb furnace with protected quench*
2. *Microcarb atmosphere control*
3. *D.A.T. three-function temperature control*

For complete information just write us at 4927 Stenton Avenue, Phila. 44, Penna.



LEEDS NORTHRUP
instruments *automatic controls • furnaces*

Now IBM uses 1010 instead of 1065



At the IBM plant in Poughkeepsie, N.Y. they refer to their protected quench Homocarb as a "problem-solver". For example, the brackets shown ½ size, formerly made of 1065 steel to meet physical requirements, presented severe forming problems. Now IBM forms these parts of 1010 steel. They are then carburized in the Homocarb furnace at 1700 F to a surface carbon content of 0.65% and direct-quenched under protective atmosphere. Physical specifications are well within specified tolerances, and cost of forming has been sharply reduced.

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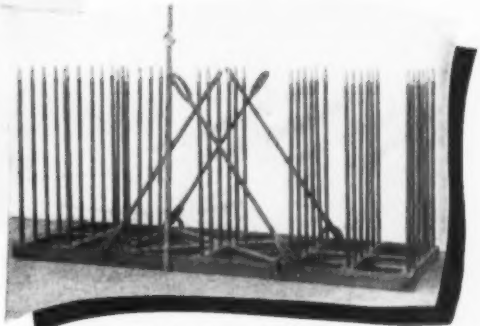
PHOTOMICROGRAPH OF
ORDINARY SAE 52100
It's Cleaner
PHOTOMICROGRAPH OF
FERROVAC 52100

WHAT'S YOUR PICKLING PROBLEM

Weldco Pickling Hooks

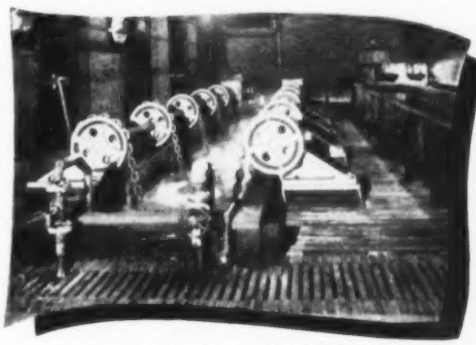
WELDCO SPECIALISTS HAVE THE ANSWER!



Weldco Sheet Pickling Crate

IN HUNDREDS of plants, you'll find Weldco equipment all along the pickling line. For Weldco products are made of corrosion-resisting, hot rolled metals, which withstand attack from hot acids and other pickling solutions. They are strong yet lightweight, wear-resistant, durable, and long-lasting. You get all these advantages when you specify Weldco hooks, mechanical picklers, crates, baskets, racks, chain, steam jets, and accessories.

Weldco offers a complete, well-designed line of pickling equipment . . . plus the services of our experienced staff. Let Weldco engineers take care of all your pickling needs. For any problem, large or small, they have the practical, cost-cutting answer.



Weldco Mechanical Bar Pickler

Weldco Mechanical Coil Pickler

Weldco Monel Chain

THE YOUNGSTOWN WELDING & ENGINEERING COMPANY

3720 OAKWOOD AVE. • YOUNGSTOWN 9, OHIO

Get a better start for your finish!

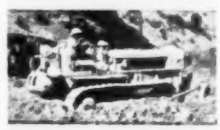
In its Peoria, Ill., plant, Caterpillar Tractor Co. uses power spray washers to remove cutting oils and rust preventives from steel and cast iron parts . . . prior to assembly or further processing. In past years, the Company has tried several types of cleaners in an effort to make the spray wash operation as economical and efficient as possible.

Some months ago a Pennsalt service man suggested a trial of a Pennsalt Cleaner. The results of the test were highly satisfactory: the Pennsalt Cleaner maintained Caterpillar's standards of quality and efficiency while proving considerably more economical. This Cleaner is now used in 71 power spray washers.

Many another plant has come to the same conclusions about Pennsalt Cleaners. They have powerful detergent effect and long working life.

The feature that makes Pennsalt Cleaners all the more remarkable—and desirable—is their economy. While outperforming competitive cleaners, they almost always prove to be considerably cheaper to use.

An experienced Pennsalt service man in your area will be glad to tell you more about the many specialized cleaning products in the complete Pennsalt line. For the name of the Pennsalt man nearest you, or for further information, write: Metal Processing Department, Pennsylvania Salt Mfg. Co., 442 Widener Bldg., Philadelphia 7, Pa.



Pennsalt Chemicals

A Report from Vanadium Corporation

How Vanadium Corporation's long-range expansion program is helping industry.

CHROMIUM ALLOYS

Vanadium Corporation's new plant at Graham, West Virginia, has been especially equipped to produce—by a unique new process—a remarkably clean, dense new *low carbon ferrochromium.* This new alloy combines a normal silicon content with a high chromium-to-carbon ratio which enables the steelmaker to produce stainless steels of extremely low carbon content without resorting to modification of furnace and melting practices.

The new Graham plant also produces various alloys of *ferrochrome-silicon.* Additional modern facilities at Niagara Falls are producing increased quantities of *high-carbon ferrochromium* by Vanadium's exclusive process. There is an ever growing demand for these clean, high-density Vancoram Alloys—particularly in the many applications where quality and economy are primary considerations.

GRAINAL ALLOYS

These are the multiple-element alloys developed by Vanadium Corporation that are now being used to produce annually over *a million tons of boron steels.* Replacing critical and more costly elements with respect to hardenability and other properties, Grainal Alloys have proved invaluable not only in times of heavy defense production but also in providing low-cost, high-quality alloy steels for our peacetime economy.

New use for Grainal Alloys: alleviating the problem of hot shortness in *stainless steels.* Field reports indicate that small additions of Grainal improve the hot working characteristics of stainless, thus cutting conditioning costs and increasing output.

Anticipating the future demand for Grainal Alloys, Vanadium Corporation has included at its new plant at Cambridge, Ohio, additional facilities for their production.

VANADIUM ALLOYS

With government restrictions on the use of vanadium now lifted, steelmakers can once again take full advantage of Vancoram *ferrovanadium.* Small additions of this versatile, economical alloy often do the work of large amounts of other, more expensive alloys—*a little goes a long way.*

Vanadium Corporation has played an important role in helping to make vanadium again available in large commercial quantities.

For example . . .

New VCA mines in Colorado have substantially increased the production of *vanadium ore* in conjunction with western uranium operations.

Complete new facilities at the Cambridge, Ohio, plant will soon be in full operation to further insure a plentiful supply of highest quality ferrovanadium for every application—from watch springs to giant forgings.

More news about Vancoram Ferrovanadium: Available for many years both in bags and drums, ferrovanadium can now be furnished palletized for greater shipping economy and ease of handling.

SILICON METAL AND ALLOYS

Among the promising new non-metallic materials developed during World War II are the Silicone plastics. Their outstanding properties include resistance to both high and low temperatures—thanks to *silicon metal* used in their manufacture.

Vanadium Corporation's new Graham plant provides the plastics industry with a dependable new source of silicon metal of highest quality.

The new Graham plant is also furnishing a complete range of silicon metal and *ferrosilicon* to the aluminum, iron, steel, magnesium and other industries.

RESEARCH

Now nearing completion at the Cambridge plant is the new enlarged Research Center. This new center contains extensive, modern facilities for the further development of all Vancoram products—which also include, *titanium alloys, master aluminum alloys,* and a complete range of *foundry alloys* for every application.

VANADIUM CORPORATION OF AMERICA

420 Lexington Avenue, New York 17, N. Y.

Producers of alloys VANCORAM metals and chemicals

PITTSBURGH • CHICAGO • DETROIT • CLEVELAND

PLANTS: Niagara Falls, N. Y., Graham, W. Va. Cambridge, Ohio

TWENTY-ONE G-E PYROMETERS insure proper distribution of temperature throughout the eighty-eight-foot zone of each furnace. This precise and extensive temperature control is a major factor in assuring a high-quality porcelain-enamel finish.

# of Porcelain Finish on Electric Ranges

brated accuracy of $\frac{3}{4}$ of 1% of full scale; (2) automatic cold-junction compensation, which adjusts for changes in ambient; and (3) high stability during changes in voltage, frequency, or humidity.

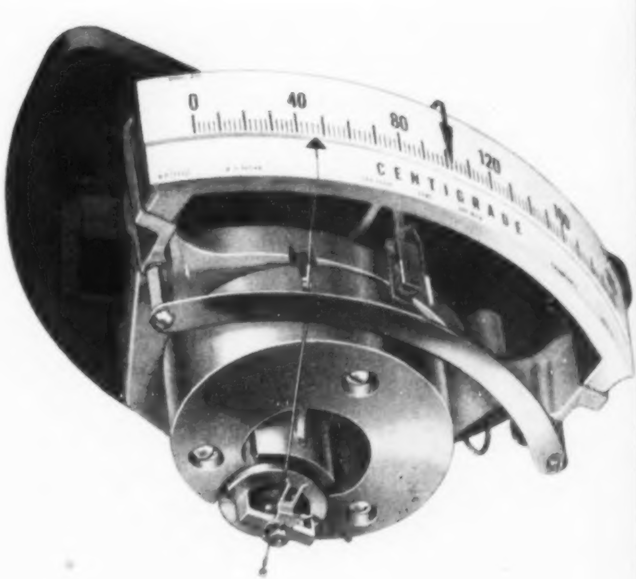
SEVERAL TYPES AVAILABLE

HP-3 pyrometers are available as indicators, indicator controllers, and protectors in either 2-position or 3-position models. Scale requirements can be fulfilled from a variety of ranges in the 0-3000 F span.

MORE INFORMATION

For complete information on how G-E pyrometer equipment can help you to improve or maintain product quality, contact your G-E Apparatus Sales representative, or write for Bulletin GEC-713 to General Electric Company, Section 602-263, Schenectady 5, N. Y.

*Manufacturers suggested retail price.



SHOCK-RESISTANT CONSTRUCTION of the General Electric HP-3 pyrometer sustains accuracy with sturdy stationary parts, 3 1/4-lb. alnico magnet, and a lightweight moving element. ▶

engineering digest OF NEW PRODUCTS

Shell Molding Machine

A new model shell molding machine, incorporating new features designed to increase output and uniformity of molds, has been announced by Shalco Engineering Corp. According to the manufacturer, the unit was specifically designed to make precision shell molding practical for all foundries. Reported to produce up to two shells per

minute, this gas or electric unit is available with automatic timers for both inversion and curing cycles. Positive alignment for precise shell duplication is claimed. A new dump box design increases uniformity and compactness of shells. Castings with tolerances as close as 0.005 in. per in. are claimed to be obtainable from Shalco shell molds.

For further information circle No. 1365 on literature request card on p. 32-B.

Dew Point Controller

An automatic dew point controller which regulates dew point in controlled atmosphere furnaces has been developed by Ipsen Industries, Inc. The new self-contained electronic unit, continuously records and controls furnace dew point for automatic carburizing and carbon restoration. Dew point settings are made by simply turning an indicator. As there is a definite relationship between the dew point of the atmosphere and its carbon potential, automatic control of the furnace dew point will assure bright, scale-free results in a wide variety of heat treating operations, including carburizing, carbonitriding, carbon restoration, annealing, normalizing and hardening. The electronic element is replaceable.

For further information circle No. 1366 on literature request card on p. 32-B.

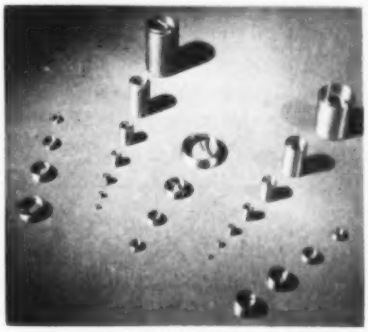
Heavy Duty Etcher

A newly designed electric etcher has been announced by the Martindale Electric Co. Its range of six heats makes it suitable for various sizes of parts. It may be left connected to the line without danger of overheating when not in use.

For further information circle No. 1367 on literature request card on p. 32-B.

Thread Inserts

Heli-Coil Corp. has announced the availability of 47 standard sizes of stainless steel wire thread inserts, five in the automotive spark plug series, 17 in the national and unified coarse thread series, six in the national pipe thread series, 15 in the national and



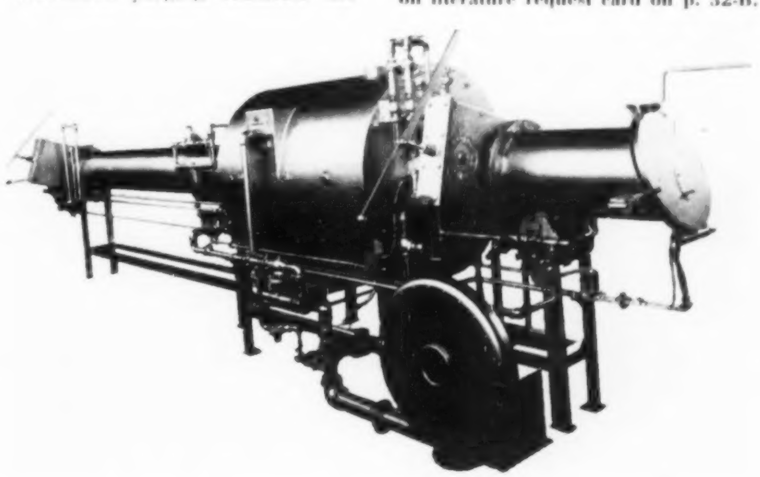
unified fine thread series, and four in the aviation spark plug series. In-

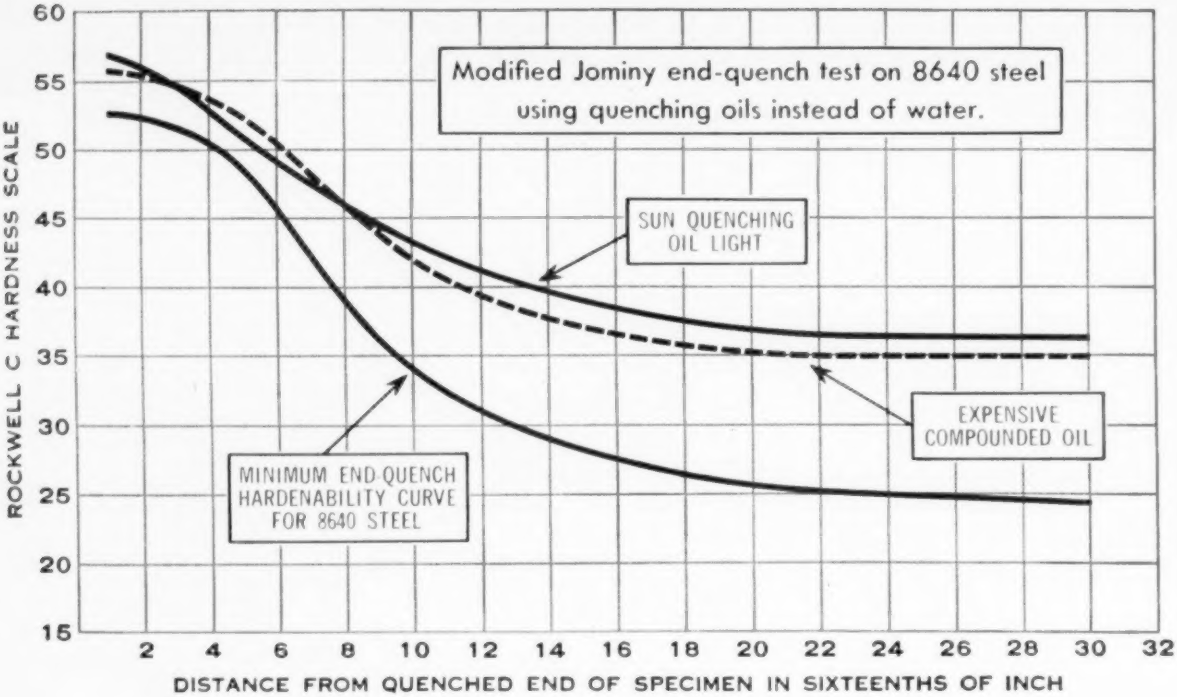
Furnace For Treating Stainless Steel

A new furnace has been built and field tested by Lindberg Engineering Co. for bright hardening and bright annealing of stainless steels and other high alloys, with no oxidation or discoloration. It can also be used for copper brazing of stainless steels. The atmosphere is controlled so that it is not contaminated by oxygen or water vapor. A full muffle prevents contaminations of the atmosphere from the combustion products.

Automatic purging chambers are located at both the charging and discharging ends. Parts are cooled rapidly in a water-jacketed chamber under the protection of the atmosphere, with water temperature automatically controlled. In the larger models, as many as four baskets of work can be in the cooling chamber at one time. Work is transferred manually from chamber to chamber by means of a pusher rod inserted into a hole in the charging door. The protective atmosphere consists of dissociated ammonia or pure dry hydrogen.

For further information circle No. 1368 on literature request card on p. 32-B.





You can do 95% of all quenching jobs by using SUN QUENCHING OILS

This has been proved again and again in industrial heat treating departments and in the laboratory. The above test curves compare the results obtained from Sun Quenching Oil Light and those from an expensive compounded quenching oil. The hardnesses obtained are far above the commonly accepted minimum.

In addition to assuring consistently uniform physical characteristics, Sun Quenching Oils prevent sludge formation and help remove any deposits that may exist. Oil coolers are kept clean; maintenance costs are decreased. Sun Quenching Oils lower operating costs too. They thin out when heated, drain off parts faster and more completely. Make-up is materially reduced.

For more information about Sun Quenching Oils and how they can help you, call your nearest Sun office or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-11.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

SUNOCO

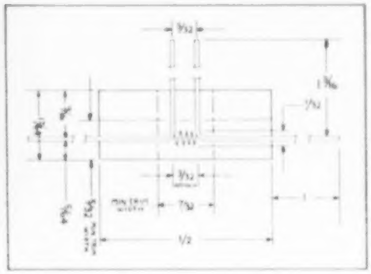
PHILADELPHIA 3, PA. ◆ SUN OIL COMPANY LTD., TORONTO & MONTREAL

serts for the national and unified thread series are supplied in 1, 1½, 2, 2½ and 3-diameter lengths.

For further information circle No. 1369 on literature request card on p. 32-B.

Smallest Strain Gage

The smallest SR-4 bonded resistance wire strain gage yet developed has been announced by the Baldwin-Lima-Hamilton Corp. The new strain gage has a gage length of only 1/32 in., half of the previously smallest gage.



It is Bakelite-base gage of the wrap-around type, with cupro-nickel wire, and is applied by phenol-resin cement. Nominal resistance is 120 ohms and the average gage factor is 1.4, guaranteed within 10%.

For further information circle No. 1370 on literature request card on p. 32-B.

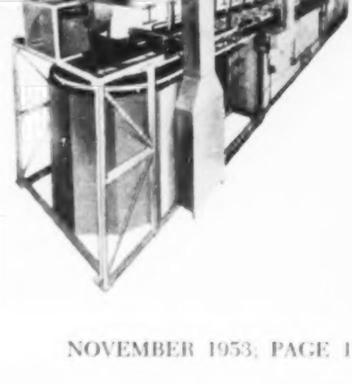
Impregnating Castings

A recently developed impregnator that stops leakage of gases in metal castings has been announced by Nelsonite Chemical Products, Inc. The new formula has worked well with aluminum and iron castings. Castings are merely immersed without use of pressure or vacuum equipment. At least three days are required for curing.

For further information circle No. 1371 on literature request card on p. 32-B.

Automatic Plating Machine

Wagner Brothers' new fully automatic electroplating machine holds interest not only for those concerned

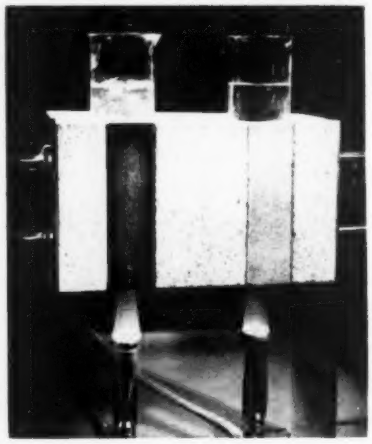


with plating but for anyone interested in automation. The new machine, now thoroughly tested in production, makes use of uncomplicated longitudinal and vertical movements. Central hydraulic power supply and control panel may be located at any convenient point. Two sets of controls allow adjustment of speed or dwell of each movement, or skipping a station entirely. Plating baskets are transferred from one tank to the next by a variable stroke hydraulic cylinder fitted with decelerating controls.

For further information circle No. 1372 on literature request card on p. 32-B.

Heat Transfer Brick

A very good thermal conductor, high-temperature brick has been announced by the Carborundum Co. This silicon carbide material is said to have thermal conductivity comparable to



hot chromium-nickel steels, and eleven times more than fireclay refractories. It is produced as a brick, cement, or in shapes for use in heat transfer applications up to 3000° F.

For further information circle No. 1373 on literature request card on p. 32-B.

High Speed Tool Steels

Latrobe Steel Co. has announced high speed steel of regular analyses, to which have been added uniformly-distributed sulphide lubricants in a new form. Latrobe claims longer tool life for these steels, now available in M-1, M-2 and M-10 types, in all sizes and shapes normally furnished.

For further information circle No. 1374 on literature request card on p. 32-B.

X-Ray Quantometer

Applied Research Laboratories introduced its new X-ray Quantometer at the National Metal Exposition on October 19th. This instrument performs rapid nondestructive analysis of metals, powders and liquids, by X-

New facts for your file on

U·S·S CARILLOY STEELS

IN THE WALKER BULLDOG TANK

special U·S·S Carilloy steel reduces the cost of critical transmission parts

The Walker Bulldog is a light combat vehicle weighing 26 tons. It is equipped with a new 76 mm. high-velocity gun, a 500-hp engine, and heavier armor than World War II tanks.

● How would you like to save $25 a ton on steel for your heavy-duty parts, *without* sacrificing quality? We bet you'd jump at the chance, just as the manufacturer of the Army's great Walker Bulldog Tank did.

U·S·S Metallurgists showed him how to make this important saving. They recommended special U·S·S developed Superkore steel for the drive gears and pinions of this powerful machine. This steel provides the required hardenability, but contains less alloy than other steels capable of doing the job. Therefore, it costs less.

Improved machinability

U·S·S Superkore also responds more uniformly to heat treatment and is easier to machine than ordinary alloy steels of equal hardenability.

U·S·S Superkore—now known as TS 43BV12 and adopted in both AMS and ASTM specs—is one example of the many important new developments that have come from the extensive research laboratories of United States Steel. From our constant effort to get the *most possible work* out of steel at the *lowest cost* to you, have come better steels for use at high temperatures—better steels for use at extremely low temperatures—steels that are easier to machine—steels that are easier to heat treat—steels that in hundreds of ways help to solve production problems and reduce costs.

Free metallurgical assistance

We may have ready for use or under development just the steel you need to solve a tough production problem. If we do, the U·S·S Service Metallurgist who contacts you will know about it. If we don't, we may be able to modify an existing Carilloy steel to suit your special requirements. In either event, it will pay to get in touch with us and find out.

If you have any question at all about alloy steels, write to United States Steel, Room 2818-X, 525 William Penn Place, Pittsburgh 30, Pa.

USS

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. • UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

heat treating down cold"

U. S. Steel Heat Treater

In the entire production of steel forgings, no single operation is more important or more finicky than the heat treating. Here, with careful heating and quenching, the forging is tailor-made to the physical properties you require.

At best, heat treating is a complicated business. And when you get into the giant forgings made at our Homestead Forgings Division, you encounter problems absolutely unknown in the production of smaller forgings. Only a handful of men in this country have the skill to do the job. One of them is Joseph Asmonga, a Heat Treater for 18 of the 25 years he has been with U. S. Steel.

Sheer *size* is a great problem and often makes liquid oil or water quenching impracticable. In the photograph, Mr. Asmonga is *air* quenching a roll arbor—and it takes him 10 hours just to reduce the temperature from about 1750°F. to 650°F.

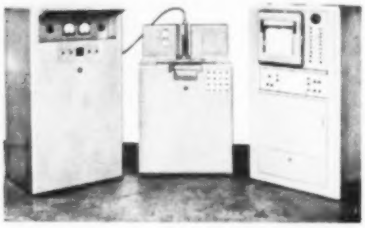
Admittedly, Mr. Asmonga has an eye-popping array of instruments, furnaces and cranes to help him—as well as a complete metallurgical staff. But when you get right down to it, it takes plain old experience and skill to change a list of specifications into a finished, precisely heat treated forging.

Joseph Asmonga is typical of the men who actually do the work on your USS Quality Forgings. All of these men have the skill, the equipment and the *determination* to give you the finest steel forgings that money can buy. Write for more information and our free 32-page booklet describing USS Quality Forgings. Address United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS *Quality* FORGINGS

- heavy machinery parts—carbon, alloy, stainless
- electrical and water wheel shafts
- hammer bases and columns
- forged steel rolls and back-up roll sleeves

ray fluorescence spectrography, and is equally adapted to laboratory or production control problems. The circuits used in the instrument can measure a



number of elements in the time required to record one element with a scanning spectrometer. It can be supplied for use of eight channels simultaneously.

For further information circle No. 1375 on literature request card on p. 32-B.

Standardized Graphite Molds

National Carbon Co. has standardized its line of graphite pig ingot molds to permit quick deliveries. Graphite molds are in use as over metal molds and in casting many special shapes of metals. The following advantages are claimed: low costs; smooth, clean, uniformly sized ingots with no chemical contamination; light in weight; will not crack, chip,

spall, fire-check or warp; quick stripping merely by upsetting; no preheating required; easy to machine or fit into mounting devices; and long life.

For further information circle No. 1376 on literature request card on p. 32-B.

Beryllium Copper

A new alloy that promises to spread the industrial range of beryllium copper into new fields was featured as one of the main exhibits of the Beryllium Corp. at the 35th National Metal Exposition. The new low-beryllium alloy is claimed to combine properties of high strength and high conductivity.

For further information circle No. 1377 on literature request card on p. 32-B.

Furnace Quality Controls

Indicating flowmeter controls for balancing heat input and furnace requirements have been announced by

Seico Instruments Div. of Grindle Corp. These custom controls are claimed to limit temperature differences of pieces in the furnace and enable proportioning of heat input to the changing rate of heat absorption. The two instruments in this control system can be adapted for either manual or automatic operation.

For further information circle No. 1378 on literature request card on p. 32-B.

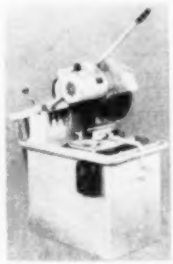
Microscope Reader

The Pacific Transducer Corp. has announced a new Brinell microscope reader for the measurement of indentation diameters for determining hardness and checking the accuracy of harness testing machines. This new 20-power microscope features a reticle in a flat-field optical system, and a self-enclosed concentrated beam of light. The 7-mm. scale is graduated in tenths of millimeters.

For further information circle No. 1379 on literature request card on p. 32-B.

Cut-Off Machine

The Stone Machinery Co. announces a regular cut-off machine that can be converted quickly for free-hand cutting of gates and risers from nonferrous castings. The machine is shown set up for free-hand cutting. As a regular cut-off machine, either abrasive or tool steel blades may be used. Capacity is 2½-in. solids, and 4-in. pipe, tubing and structurals. This machine can cut materials at less than 4 sec. per sq. in. of metal.



For further information circle No. 1380 on literature request card on p. 32-B.

Tool Cooling

A new coolant has been announced by the Air Conversion Research Corp. This portable unit can accommodate up to 16 cutting operations. It operates on the expansion-cooling of gas refrigeration principle. Coolant is forced into a high velocity air stream where it is atomized into a fine mist. It is then directed to the tool through

a centrifugal distributor, flexible high-pressure tubing and nozzle. The coolant solution is cooled below room temperature and cools the tool; the jet action carries away tool heat and keeps chips out of the way.

For further information circle No. 1381 on literature request card on p. 32-B.

Stereoscopic Microscope

To permit greater speed, convenience and versatility in stereoscopic microscope work, the Galileo Co. has announced three exclusive design improvements in its stereoscopic microscope: A 180° rotating binocular head, a three-way stand, and a novel quick-change nosepiece. The rotating binocular head is inclined at a comfortable 30° angle and turns on a vertical axis to permit either normal or inverted observation. The stand sits extra low for greater comfort and convenience. The microscope will accept objects up 11 cm. high. If the base support is removed, the unit can be placed directly on the object to be examined.

For further information circle No. 1382 on literature request card on p. 32-B.

Vacuum Melting

U. S. Patent 2,625,719 has recently been granted to the National Research Corp. covering continuous vacuum melting furnaces. This new development makes it possible to charge raw material and remove vacuum-cast ingots from furnaces without the necessity of cooling the crucible or breaking the vacuum in the melting chamber.

For further information circle No. 1383 on literature request card on p. 32-B.

Spectrograph

A versatile new 1.5-meter stigmatic grating spectrograph designed to bring precision spectrography within

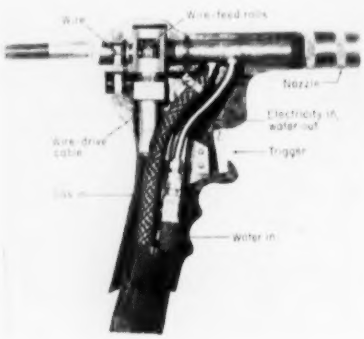
the reach of small firms, has been announced by the Bausch & Lomb Optical Co. The instrument is avail-

able in two models which provide different dispersions, resolving powers and plate coverages. Both are capable of analyzing a wide range of materials. For ease in manipulation, all parts are located at the same end of the instrument. Exposure time of several seconds provides a high degree of sensitivity for trace elements.

For further information circle No. 1384 on literature request card on p. 32-B.

Consumable-Electrode Gas-Shielded Welder

New welding equipment for the consumable-electrode, gas-shielded welding process has been announced by the General Electric Co. Called Fillerarc, the apparatus is expected to advance the field of application of high-speed, high-current-density, gas-shielded welding, which heretofore has been hampered by the necessity of using existing welding generators not specifically designed for this process. Electrode wire of aluminum, stainless steel, mild steel, copper, magnesium and other alloys may be employed in the Fillerarc equipment with argon or helium shielding gas. The process can be used in downhand, vertical, or overhead positions to weld aluminum of any alloy in thicknesses from 1/32



to 3 in., and stainless steel from $\frac{1}{16}$ to 1 in. It is also suitable for welding aluminum bronze, nickel and magnesium.

Fillerarc equipment consists of three main components: a special self-regulating motor-generator type welder, a pistol-like holder, and an electronic wire-drive unit. The generator is unlike any others used in this process. Rated at 450 amp. continuously, it has a rising volt-ampere characteristic. As current is produced, the voltage generated increases, making the process completely self-regulating. Designed to give constant arc length, the new welder produces any current required up to its full rating. Thus, it is prepared for any wire feeding speed and will supply the current necessary to melt off the wire at exactly the rate it is fed. Machine settings are for arc length only; no current calibrations appear on the dial.

The Fillerarc gun contains knurled feed rolls for pulling the electrode wire from a spool mounted in the wire drive unit, a trigger to control wire feed and gas flow, and an electrical contact tip. It is water cooled with a rating of 400 amp. continuous d-c. The gun is capable of feeding wire from 0.030 to 0.093 in. in diameter. The feed can be adjusted from 0 to 750 in. per min., and the set speed is held constant by an electronic motor control in the wire drive unit. Fingertip control provides gas coverage before and after arc is struck.

For further information circle No. 1385 on literature request card on p. 32-B.

Cut Wire Shot

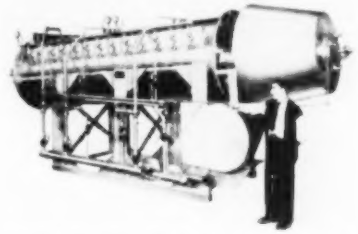
Shot cut to form cylinders of a length equal to the diameter of the wire has been announced by Harrison Abrasive Div. Uniformity of size means that each particle provides the same impact and the same finish without the wasted energy of throwing shot, without producing the desired results. This L/D cut-wire shot is available in steel, copper and stain-

less steel in a range of wire diameters from 0.0625 to 0.020 in. in various length-to-diameter ratios, and with a minimum hardness range of 36 to 46 Rockwell C, depending on the wire diameter.

For further information circle No. 1386 on literature request card on p. 32-B.

Control Zones Furnace

Three separate zones of temperature control is an outstanding feature of the latest rotary retort furnace built by American Gas Furnace Co. External controls permit the operator to regulate the temperature at will in any one of the three zones, divided about equally over the length of the furnace. This permits "on and off"



operation during the idling periods, very high input when producing work, and variation for special heating needs. Up to 1000 lb. of nonferrous parts per hour can be handled by the heated work space, which is 15 in. in diameter by 10 ft. long.

For further information circle No. 1387 on literature request card on p. 32-B.

Heat Treating Pots

Pressed steel pots for heat treating furnaces, metallized to give up to 200% longer life, have been announced

by the Eclipse Fuel Engineering Co. These new pots are available with metallized coatings for temperatures up to 1500° F.; from 1500 to 1700° F. and for 1700° F. and over.

For further information circle No. 1388 on literature request card on p. 32-B.

Cleaner

Detrex Corp. has developed a new metal cleaner especially for the vitreous enameling industry. The cleaner is a medium-high alkaline compound with high wetting and penetrating properties. It will emulsify large quantities of mineral oils and greases and keep them in suspension.

For further information circle No. 1389 on literature request card on p. 32-B.

Accelerated Salt Bath Quench

A simple method of sharply improving both the quenching and tempering action of salt baths—without cost—was demonstrated publicly for the first time by American Cyanamid Co. at the Metal Show. Water added to a nitrate-nitrite bath while it is in a molten state results in the following advantages: *(a)* it will operate at temperatures lower than 275° F. while other baths are limited to 300° F.; *(b)* the bath maintains its original composition for long periods of time below the mixture's boiling point; *(c)* martempering and hot-quenching operations take place at accelerated quenching rates; *(d)* specific degrees of hardening may be obtained by altering the amount of water in the bath, a unique characteristic since the controlling factor is the bath composition rather than the alloy content of the steel; *(e)* the bath can be easily restored to the more conventional type by raising its temperature to eliminate the water; *(f)* the new type bath involves no added costs. Water

can be added without violent splattering if the bath is agitated and below 350° F., despite the fact that this is more than 100° F. above the temperature at which water turns to steam. Nitrate and water molecules apparently become bonded before the water reaches the boiling point. The development represents an unusual exception to a widespread safety practice in the metals industry which calls for water always to be kept away from molten salt baths. The exception is made possible only by following detailed recommended procedures.

For further information circle No. 1390 on literature request card on p. 32-B.

Ceramic Coatings

The General Ceramics and Steatite Corp. announces the availability of several ceramic coatings and enamels, for application to various alloys and aluminum. Samples will be available for evaluation of such properties as oxidation protection, high temperature insulation, and radiant energy reflectance.

For further information circle No. 1391 on literature request card on p. 32-B.

Sprayed Insulation

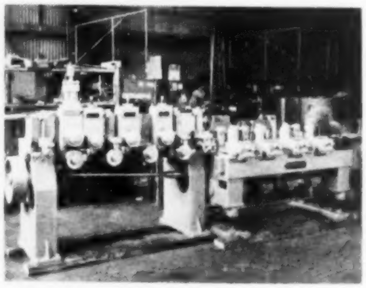
A new quick-drying material that can be sprayed like paint on metal making the treated surface capable of withstanding temperatures as high as 5000° F. has been announced by B. F. Goodrich Co. A 1/16 in. coating of the new insulation protects metal for as long as 10 sec. against flame

temperatures hotter than the melting point of metals. Pyrolock is described as a water-base inorganic material. It is nontoxic, nonflammable, nonexplosive and will adhere directly to clean metal surfaces without sandblasting or use of priming surface preparations.

For further information circle No. 1392 on literature request card on p. 32-B.

Straightening Machine

The Medart Co. has released details on a new shape-straightening machine, a two-plane variable-center type, incorporating overhung rolls



which allow quick roll change from one shape of workpiece to another. All of the rolls may be moved independently to allow set up with any given bending span up to the length of the bed. Feeding and re-forming are accomplished by simply moving one roll directly opposite another.

For further information circle No. 1393 on literature request card on p. 32-B.

High-Purity Carbon for Spectrographic Analysis

A high-purity spectrographite rod for critical chemical and metallurgical analysis by the spectrographic process has been announced by the Stackpole Carbon Co. The new PG4 rod has less than 0.001% of impurities. It is supplied in lengths up to 12 in. and in diameters of 1/8, 3/16, 1/4 and 5/16 in.

For further information circle No. 1394 on literature request card on p. 32-B.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

1405. Abrasion Tester
Bulletins on durable precision instrument for testing resistance of surfaces to abrasion. *Taber Instrument*

1406. Abrasive Belt
Folder on belt for finishing carbide tools. *Behr Manning*

1407. Abrasive Testing
Bulletin No. 6 on methods of running production tests on metal abrasives. *Harrison Abrasive Div.*

1408. Adhesives
Bulletin describes polyurethanes and their use in bonding steel to steel, aluminum to aluminum, magnesium to aluminum. *Monsanto Chemical*

1409. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1410. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1411. Alloy Tools
44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

1412. Aluminum Bronze
Bulletin 33 on properties and uses of Ampco metal. *Ampco*

1413. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1414. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

1415. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

1416. Aluminum Strip
20-page book gives technical data on five grades of aluminum strip. *Scovill*

1417. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

1418. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

1419. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

1420. Analysis of Nickel
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

1421. Anodizing
Data on aluminum racks with copper hooks for anodizing. *National Rack*

1422. Anodizing Magnesium
Article on a new anodic coating for magnesium. *Dow Chemical*

1423. Arc Welding
8-page reprint on weld tests on mild steel welded with inert-gas metal-arc method. *Air Reduction*

1424. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

1425. Atmosphere Furnace
Booklets H 53-8 on batch-type radiant tube furnaces for gas carburizing, marquenching, dry cyaniding, and other heat-treating operations. *Surface Combustion*

1426. Atmosphere Generators
12-page booklet on gas producers describes equipment and gives data on composition and applications of atmospheres. *Bellevue Industrial Furnace*

1427. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

1428. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chemical*

1429. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

1430. Blackening Compounds
Bulletin on blackening compounds (for ferrous alloys) to AMS Spec 2485. *Swift Industrial Chemical*

1431. Black Oxide Coatings
Data on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1432. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

1433. Black Oxide Finish
Four-page article "Low-Cost Black Oxide Finish on Steel by Chemical Dip Method". *Mitchell-Bradford*

1434. Blast Cleaning
24-page Bulletin 400 on blast cleaning installations for large work. *Pangborn*

1435. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

1436. Bright Annealing
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

1437. Bright Carburizing
Job data on bright carburizing and hardening gears. *Ipsen*

1438. Bronze
12-page bulletin on properties and uses of continuous cast bronze rod and tube. *American Smelting & Refining*

1439. Burner
Catalog 410 describes proportioning oil burner. *Hauck*

1440. Burners
Bulletin on combination gas and oil burner. *Ra-Diant Products*

1441. Carbon Analysis
Folder describes method of rapid carbon determination. *Leitz*

1442. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical and process fields. *National Carbon*

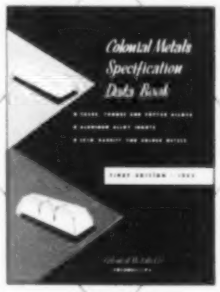
1443. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

1444. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs. time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

1445. Casting Specifications
Design values for five grades of heat resistant castings. *Ohio Steel Foundry*

1404. Nonferrous Alloys

A large body of specification data on nonferrous ingots and castings has been assembled in the newly released 1953 edition of the Specification Data Book. The spiral-bound 84-page book presents in three sections data on brasses and bronzes, aluminum



alloys, and lead, solders and babbitts. Each section begins with a table which compares Federal, Navy, Military, ASTM and SAE specifications at a glance. Detailed composition and property data for each specification appear on the following pages of the sections. Tabbing the sections has made the book easy to use. *Colonial Metals Co.*

1446. Castings, Bronze
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

1447. Centrifugal Castings
62-page book on centrifugally cast iron, steel, gray iron parts. ASTM specifications. *American Cast Iron Pipe*

1448. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

1449. Cleaners
12-page catalog on metal cleaners. Table of recommended practices. *Klem Chemicals*

1450. Cleaning
Bulletin on equipment for cleaning and pickling of shell cases and other ordnance items. *Alvey-Ferguson*

1451. Cleaning Compounds
16-page manual on finishing method for deburring and burnishing small metal parts. Compounds for heat treat scale removal and rustproofing. *Minnesota Mining & Mfg.*

1452. Cleaning Equipment
Folder on degreaser. Data on different models. *Circo Equipment*

1453. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

1454. Cold Finished Steel
8-page bulletin on selection, use, relative cost of cold finished carbon steel bars. *Ryerson*

1455. Combustion
Bulletin AD-607 on oxygen index of combustion processes. *Arnold O. Beckman*

1456. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1457. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

1458. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

1459. Core Oils
Bulletin describes core oils, pastes, washes and binders. *Pelron*

1460. Corrosion Resistance
35-page booklet on plastic materials of construction. *Atlas Mineral Products*

1461. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

1462. Cutting Compounds
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

1463. Cutting Fluids
Cutting and grinding fluid selector for various machining operations. *D. A. Stuart*

1464. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

1465. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

1466. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1467. Die-Casting Machines
22-page catalog shows complete line of die casting machines. *Kux Machine*

1468. Die Sets
24-page catalog on all steel die sets and supplies. *Superior Steel Products*

1469. Electric Furnaces
Brochure on electric heat treating, melting metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1470. Electrical Steel
80-page book of engineering data on silicon steels for the electrical industry. *Republic Steel*

1471. Electron Microscope
New 20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

1472. Electroplating
Folder on new process for electroplating intricate precision parts with precious or common metals at controlled tolerances. *American Electro Products*

1473. Enamel on Aluminum
Bulletin 2001 on application of porcelain enamels on aluminum alloys. Procedures in selection of alloys, application of enamel, correction of defects. *Pemco Corp.*

1474. Extruded Cylinders
Bulletin on extruded steel cylinders with smooth surfaces and no taper. *Mullins Mfg.*

1475. Extrusion Presses
8-page bulletin on presses designed for extrusion of aluminum, brass and other nonferrous metals. *Lake Erie Engineering*

1476. Fasteners
68-page catalog of screws, bolts, nuts, washers. *Interstate Screw Corp.*

1477. Fatigue Testing
12-page bulletin on Schenck universal dynamic fatigue machines for oscillating reversed stress, push-pull fatigue testing, torsion tests, single-direction stressing and endurance life tests. *R. Y. Ferner Co.*

1478. Filters
8-page bulletin on dimensions and capacities of industrial filters. *Industrial Filtration Co.*

1479. Finishing
Book, "Abrasive Grain and Powders for Use in Metal Finishing". *Abrasives Div., Carborundum*

1480. Finishing
52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

1481. Finishing
Catalog A-653 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1482. Finishing Compounds
8-page booklet on compounds for barrel finishing. Methods of deburring, surface finishing and precision finishing. *Minnesota Mining and Mfg.*

1483. Finishing Systems
Bulletin on cleaning and rust-proofing equipment, spray booths and drying ovens. *Peters-Dalton*

1484. Flaw Detection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1485. Flow Meters
16-page catalog on meters for flow rate measurement of liquids and gases by variable area method. *Fischer & Porter*

1486. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

1487. Flow Meters
24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

1488. Flux, Aluminum Melting
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals and Metals*

1489. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Tables, drawings. *Merrill Bros.*

1490. Forgings
32-page engineering manual of brass and aluminum forgings. *Mueller Brass*

1491. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

1492. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

1493. Forming Dies
Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

1494. Forming Dies
Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

1495. Forming Jaws
Bulletin on Hydra-Curve jaws with flexible action for sheet forming. *Hufford Machine*

1496. Foundry Practice
Article on why castings are lost; from "Lavingot Technical Journal". *Lavin*

1497. Foundry Wash
Bulletin on zirconite all-purpose paste wash for foundry applications. *Titanium Alloy Mfg.*

1498. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1499. Furnace Controls
Bulletin on instruments and controls for heat treating furnaces. *Hays Corp.*

1500. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1501. Furnace Maintenance
16-page "Maintenance Guide for Electric Heat Treating Furnaces" on preventive program. *Hevi Duty Electric*

1502. Furnaces
Reprint on forming and heat treating spring harrow teeth at Mid-West Forge & Mfg. Co. *Flinn & Dreffein*

1503. Furnaces
40-page book describes gas and electric furnaces and applications. Four basic types of atmospheres. Glossary of heat treating terms. *Westinghouse*

1504. Furnaces
Folder describes complete setup for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1505. Furnaces
12-page Catalog I-2 on method of atmospheric control for hardening high speed steel. *The Sentry Co.*

1506. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1507. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1508. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

1509. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

1510. Furnaces, Laboratory
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

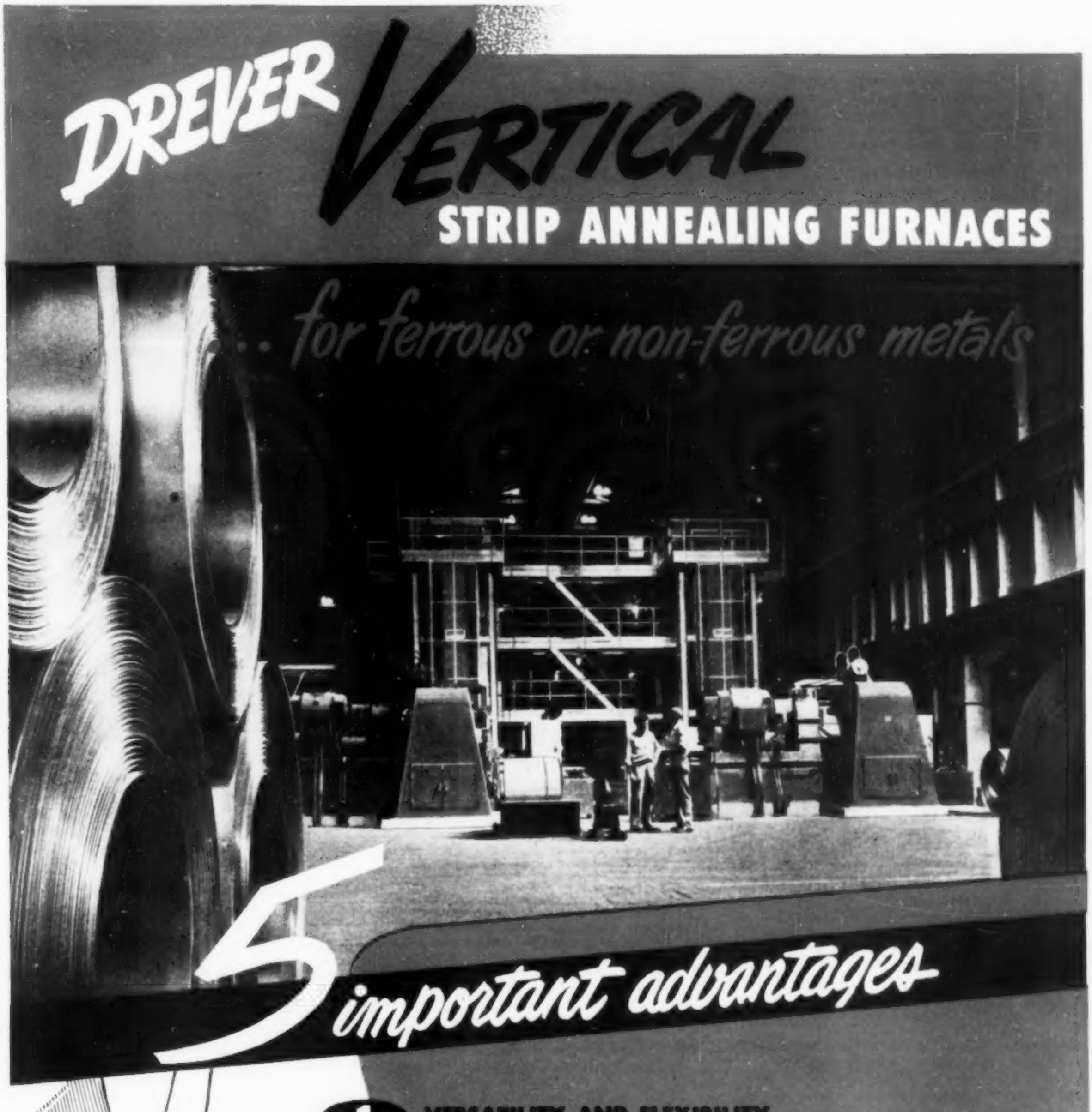
1511. Gamma Radiography
Data file on equipment and sources for cobalt 60 radiography in industry. *Technical Operations*

1512. Gold Plating
Folder on salts for bright gold plating. Also lists equipment needed. *Sel-Rex*

1513. Graphite Electrodes
164-page vest-pocket data book on graphite electrodes and electric-arc furnace practice. *International Graphite*

1514. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1515. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. *Lindberg Steel Treating Co.*


DREVER VERTICAL
STRIP ANNEALING FURNACES
.. for ferrous or non-ferrous metals
5 important advantages
1 VERSATILITY AND FLEXIBILITY
2 ABSOLUTE UNIFORMITY OF ANNEAL
3 MINIMUM FLOOR SPACE REQUIRED
4 HIGHLY ECONOMICAL AND EFFICIENT
5 ELECTRIC OR RADIANT-TUBE-GAS-FIRED HEATED
● Illustrated are two 1820-KW, 20,000 lbs/hr Vertical Strip Continuous Annealing Furnaces for 42" wide strip.

1516. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 inches round and flat. *Ames Precision*

1517. Heat Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

1518. Heat Treating
72-page catalog on carburizing, cyaniding, brazing, austempering and annealing processes. *Ajax Electric*

1519. Heat Treating Aluminum
Bulletin on furnaces for aging, annealing, heat treating and forging aluminum. *Morrison Eng'g Corp.*

1520. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div., Allied Chemical & Dye*

1521. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1522. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

1523. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

1524. Heat Treating Stainless
84-page book on heat treating stainless steels, both martensitic and austenitic. *Republic Steel.*

1525. High Speed Steel
8-page bulletin on M-2 type high speed steel. *Latrobe*

1526. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

1527. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

1528. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

1529. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

1530. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

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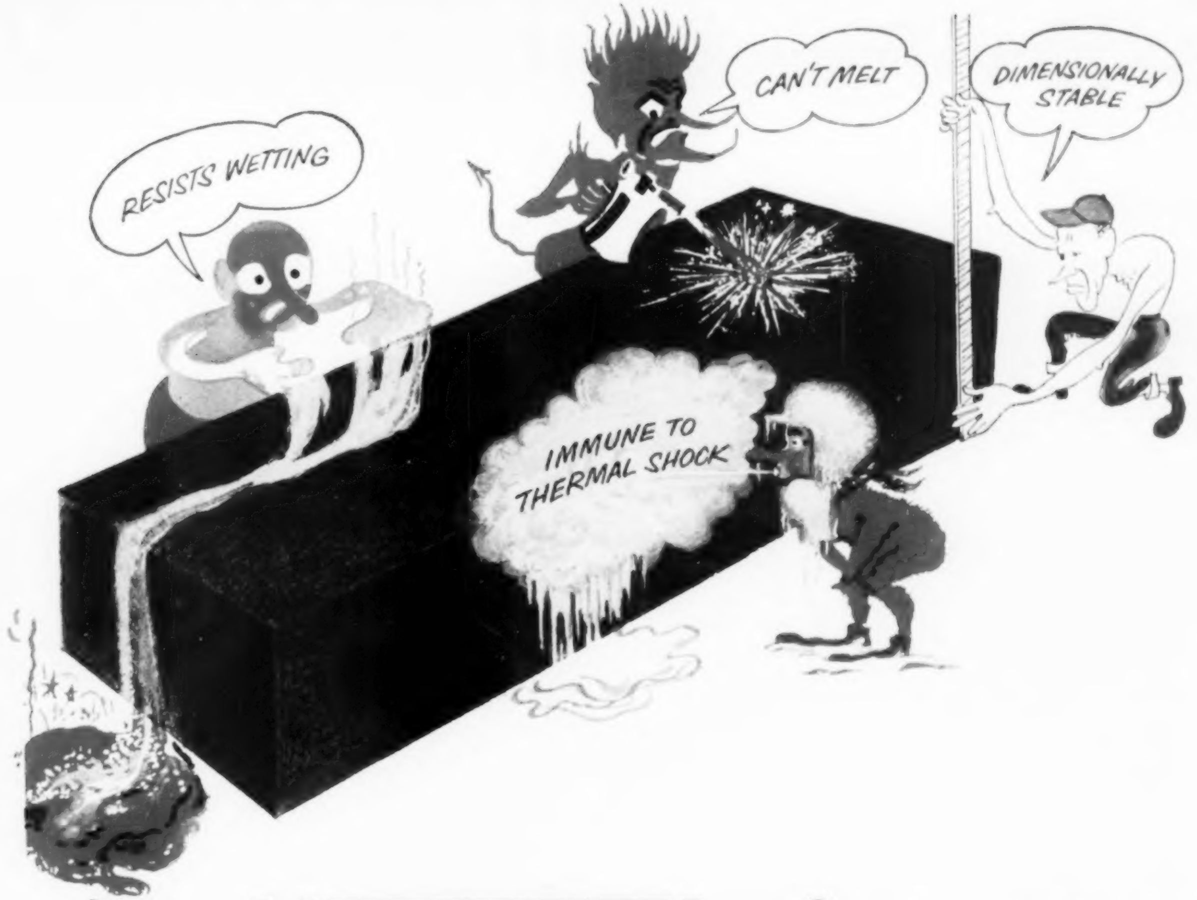
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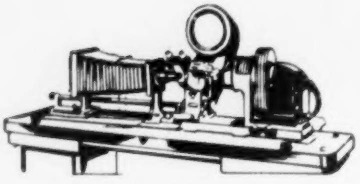

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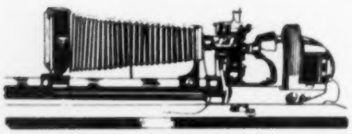

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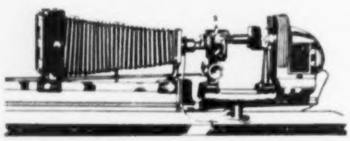

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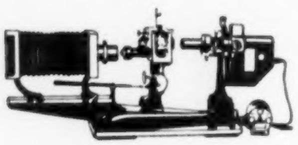

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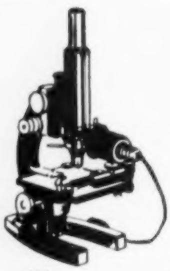

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MAGNESIUM FINDS INCREASING FAVOR AS DIE CASTING METAL

Advantages of light weight, easy machinability and competitive cost make Magnesium preferable for many types of die castings

Many manufacturers are taking a new look at magnesium as a die casting metal. In today's competitive markets, magnesium offers advantages that can't be overlooked.

Take light weight. Magnesium is the world's lightest structural metal. Where weight is a competitive factor, magnesium is the metal to use. A manufacturer of portable electronic dictation equipment found that nineteen castings in zinc weighed 13 pounds, 6½ ounces; and *in magnesium, 3 pounds, 10 ounces.* That's real weight saving!

Magnesium is well known as the easiest of all metals to machine. This in itself promotes economy. As an example, the manufacturer of a lubricating machine found that the cost of machining an oil reservoir cast in grey iron was $2.05 while machining the same part cast in magnesium cost only 80¢.

Cost-wise, magnesium is better than competitive in numerous applications. One large automotive manufacturer (an industry where cost is figured on a fractional basis) has found magnesium die castings to be the lowest in cost of any metal in a score of applications. Moreover, magnesium's long-time record of price stability is also an important factor.

Now's a good time to take a close look at magnesium. For the competitive markets ahead, magnesium can offer you many advantages. Your nearest Dow office can give you up-to-the-minute information. Or write THE DOW CHEMICAL COMPANY, Magnesium Department, Midland, Michigan.

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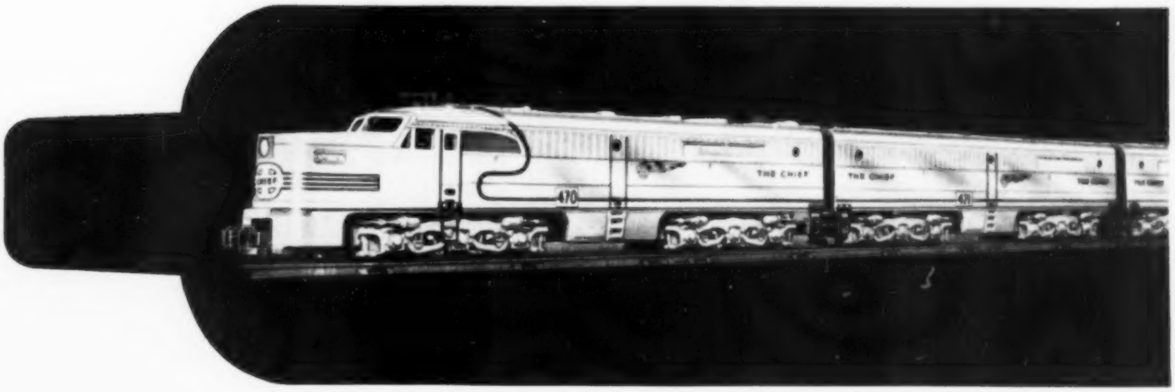
How Armour ammonia cuts costs in sintering powdered metal parts



A. C. Gilbert uses a protective atmosphere of dissociated ammonia to sinter 102 parts for this American Flyer model train

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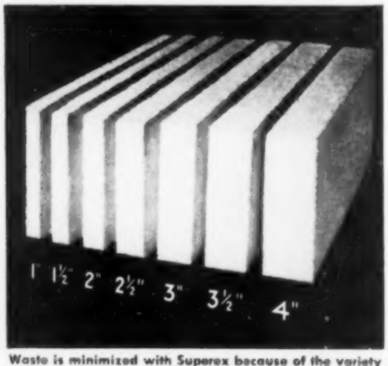

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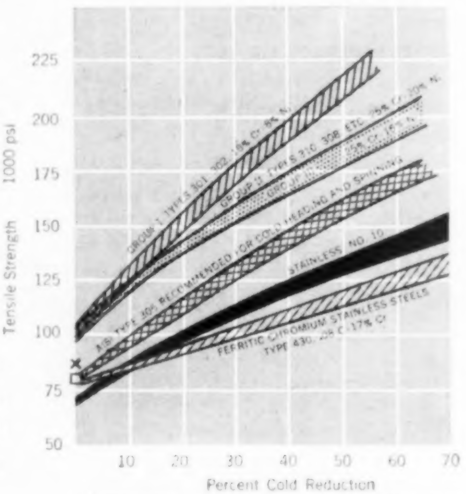

Comparison of various Stainless Steels showing increase of tensile strength with percentage of cold reduction.

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Pioneering in Improved Tool, Alloy and Stainless Steels Through Continuing Research

Here you see a long life Incoloy hydrogen annealing retort going into the furnace at L. & R.'s shop where it will soak at 2050° F. for 4 hours, then be gradually cooled to room temperature. It was fabricated by the NEWARK METAL PRODUCTS CO., Kenilworth, N. J., from 1100 pounds of Incoloy.

56-Hour Work Week a Year

...Incoloy retort still going strong at temperatures up to 2050°

Latest reports on Incoloy®, new companion alloy to Inconel®, include some remarkable service records.

As a hydrogen annealing retort, for instance.

Here — where other metals failed quickly, some in as little as 42 hours — Incoloy has already given over 3,000 hours of service. And it's still going strong.

This Incoloy annealing retort is being used by L. & R. HEAT TREATING COMPANY in Newark, N. J., for heat treating T.V. shields, hearing aid components, and laminators for servo-motors.

What an ordeal this retort goes through!

First, after being loaded, the retort is soaked at 2050°F. for 4 hours. Then the temperature is reduced 100°F. hourly until the retort reaches 1200°F. It is held there an hour and then allowed to cool to room temperature. *A total heat of 11 hours.* And it has to go through this grind four times a week!

L. & R.'s Incoloy retort has been in service a year now and it's still in shape for more of the same.

Their engineers, still watching Incoloy's record, already say service has been "very satisfactory."

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If you would like to learn more about Incoloy, write for your copy of "Preliminary Report on Incoloy."

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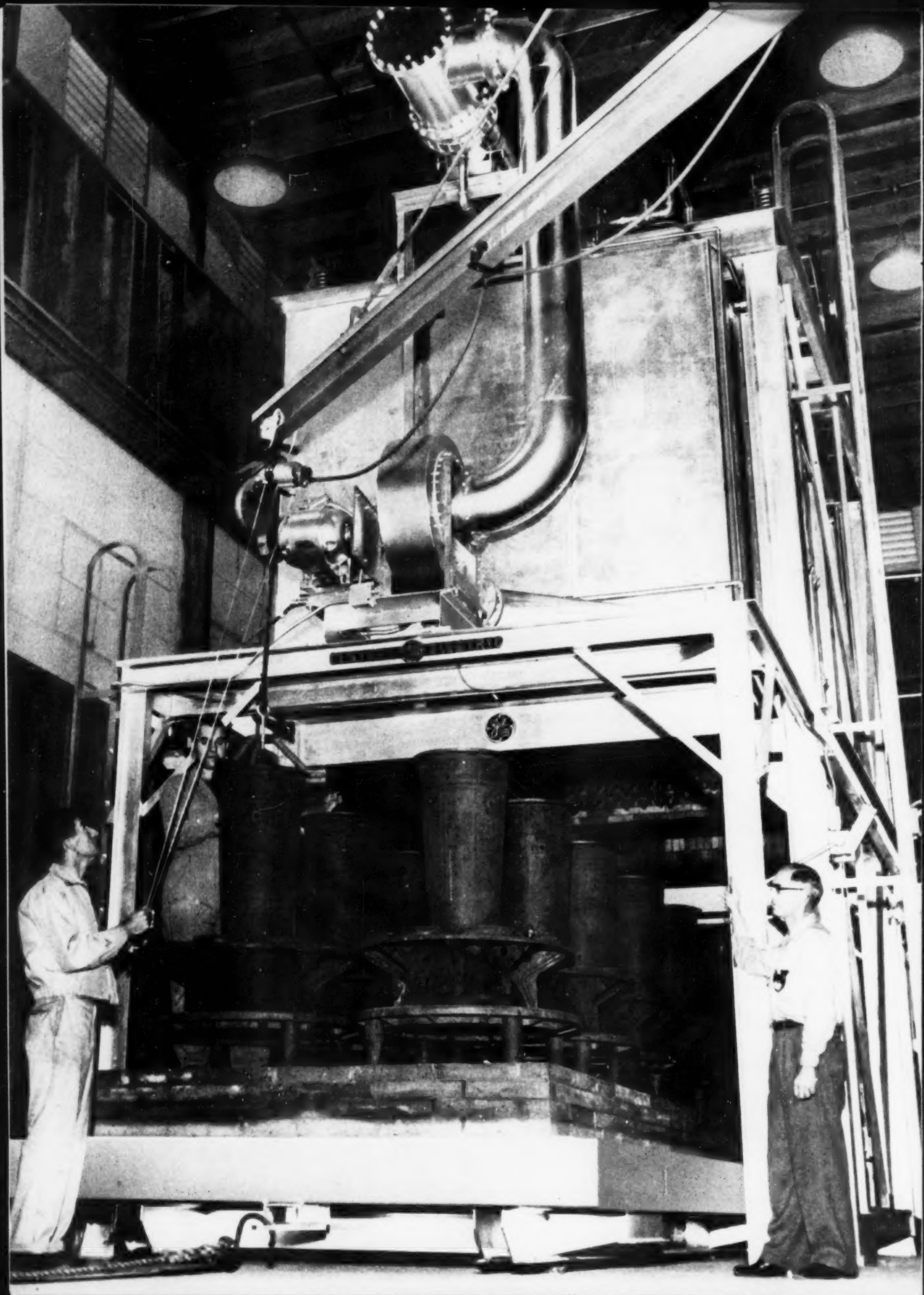
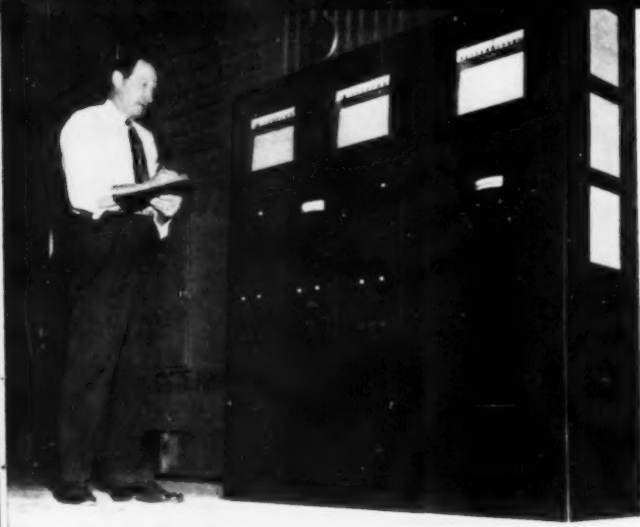
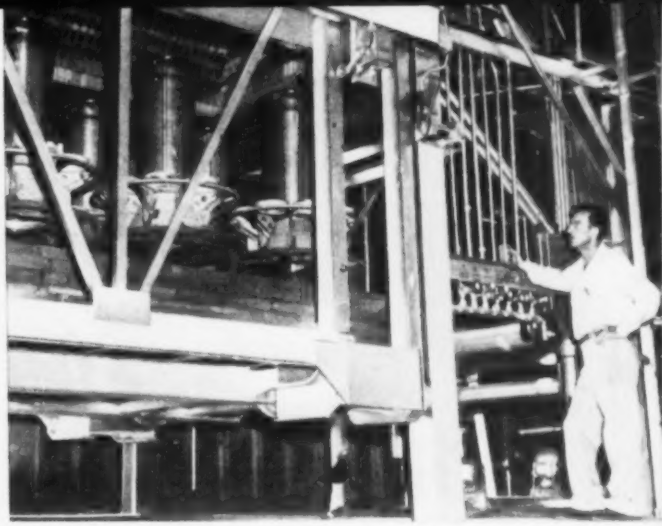




PROPER CONTROL AND TIMING of the complete heating cycle is provided by the G-E heating control unit above. To assure efficient furnace operation and uniform heating of parts, the unit provides automatic programming of heating and cooling cycles.



ONLY ONE OPERATOR is required to supervise temperatures, pressures, cooling phase, and atmospheric conditions. To minimize oxidation of jet parts a G-E gas converter, right, supplies gases of varying analyses as required by the heating cycle.

Solving Ryan's complex heating problem speeds nation's jet engine production

Key to success of America's jet engine program are the subcontractors who back up the large jet engine producers. One of these subcontractors is Ryan Aeronautical Co., San Diego, Cal. In setting up their jet aft frame production, Ryan had the problem of relieving residual stresses without distorting the metal.

After studying the problem with General Electric engineers, Ryan specified a furnace that would provide uniform heating and cooling at 200 F. per hour. Fast production at low cost was also necessary.

Applying years of experience gained in the development of America's first jet engine, G.E. designed and built a special elevator furnace that allows automatic program control of the complete time temperature cycle. This assures uniform heating of each part without weakening the metallurgical structure.

STRESS RELIEVING JET AFT FRAMES in this specially designed elevator furnace is accomplished with minimum distortion of metal. Constructed to assure low-cost, high-quality heat treatment the furnace is the result of years of G-E heating research.

Fast cooling is provided by a special blower system that extracts hot air from the furnace, cools it, and then blows it back into the heating chamber. Elimination of costly reducing operations is made possible by using a G-E atmosphere converter to minimize oxidation of the aft frames. As a result Ryan receives consistently high-quality heat treatment.

Heat losses and atmosphere consumption are reduced to a minimum by a specially designed loading car that rolls under the furnace and is hoisted by electric motors to form a completely heat-sealed furnace bottom.

RYAN GETS VALUABLE INSTALLATION SUPERVISION

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Investigate the many Norton ℞ refractories — prescribed and engineered for individual applications — that are saving users time and money in a wide range of refractory applications. See your Norton representative, or write to NORTON COMPANY, 330 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

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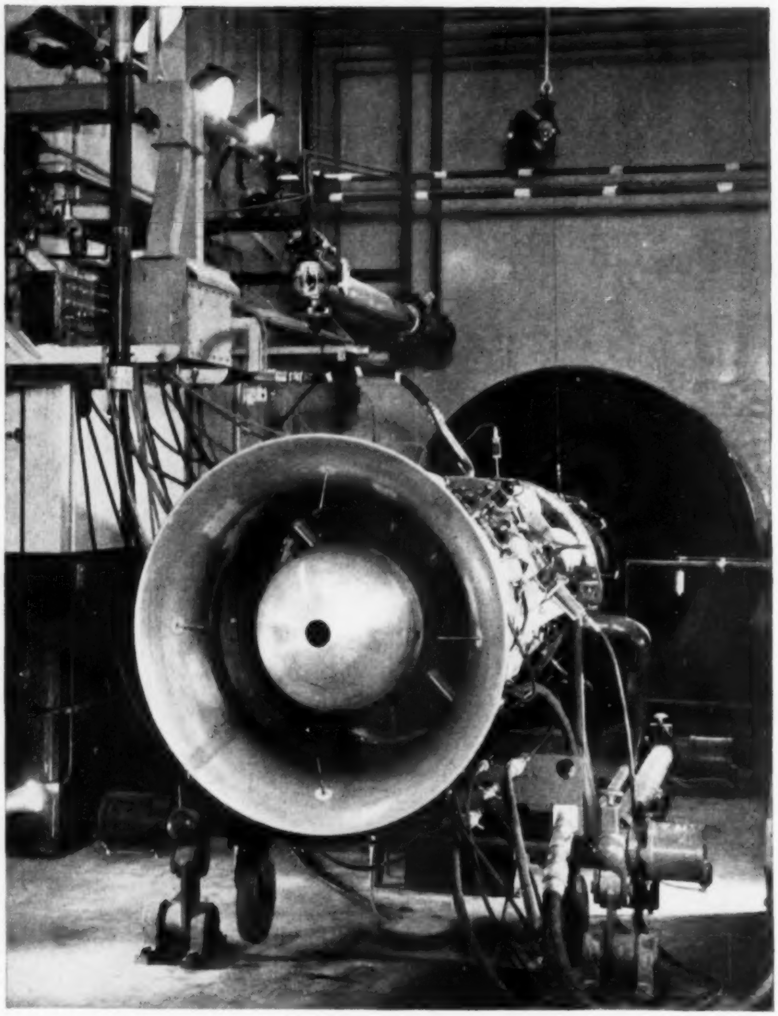
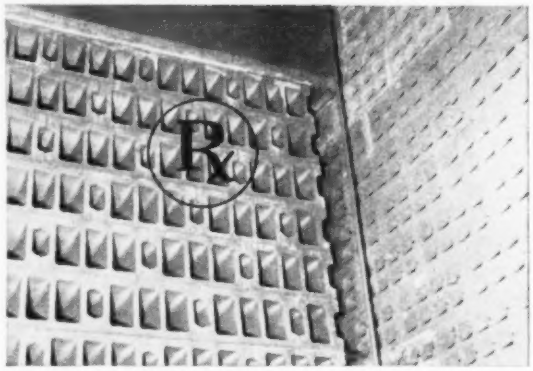


Ready to Roar. A J-47 turbo-jet engine hooked up for testing in the Studebaker plant. Note opening of augmenter tube at rear of test chamber.



"The Shock Absorber." This movable buffer wall of CRYSTOLON blocks, directly behind the augmenter tube, protects the testing installation by dissipating the exhaust blast.

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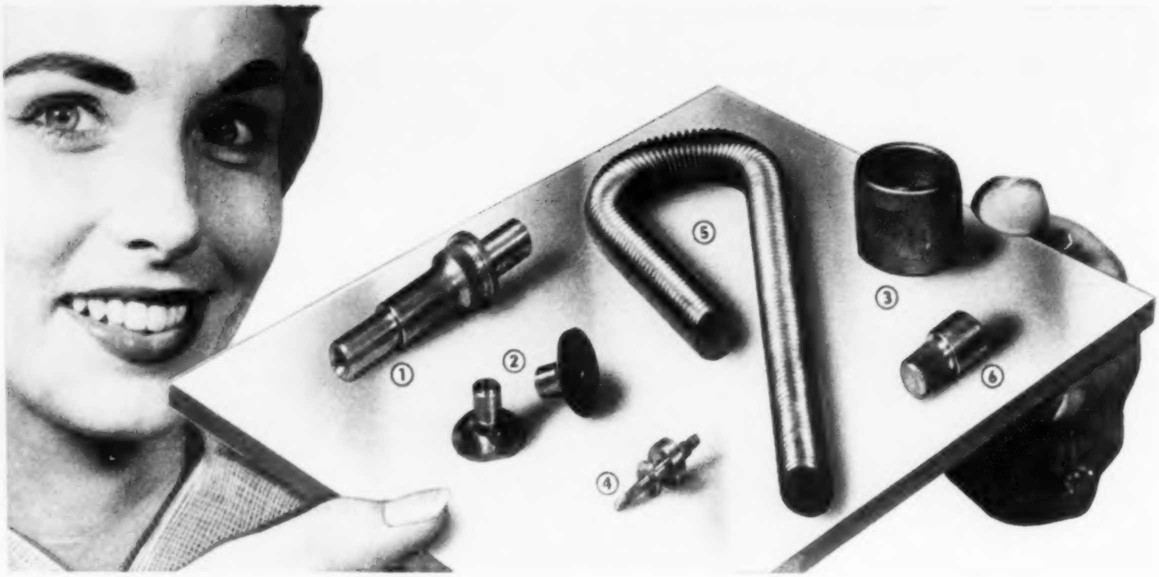

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increases production 43%

It is almost too good to be true—but, in Ledloy, lead actually lubricates the steel during machining, permitting greatly increased feeds and speeds. On job after job in shops throughout the country Ledloy is effecting net savings of 25% or more because it machines 30% to 50% faster than B-1113 and extends tool life as much as 200%.

The lead in this remarkable open hearth steel is so finely dispersed it cannot be seen with a microscope. Yet it reduces the friction between chip and cutting tool substantially. And Ledloy machines to an unusually clean smooth finish—case hardens effectively—bends, crimps, swedges or rivets easily.

Your nearby Ryerson plant now has large stocks of Ledloy rounds, squares and hexagons in a wide range of sizes. So get all the facts from your Ryerson representative or write for engineering data on Ledloy. And call Ryerson for quick shipment of this remarkable new free-machining steel.

How Ledloy Cut Costs on These Parts

1. *__BEATER SHAFT__—production increased 43% when shop switched to Ledloy from C-1117. Part is case hardened to 60-62 Rockwell C.
2. *__GOLF SHOE LUGS__—Ledloy succeeded where free-cutting Bessemer steels failed in this swedging operation. Took inside threads perfectly.
3. *__UNIVERSAL JOINT SOCKET__—formerly made from C-1117, production rose 72% with Ledloy. Part is case hardened to 60-62 Rockwell C.
4. *__DRIVE SHAFT__—result of changing from B-1113 to Ledloy: production increased more than 35%, over-all costs decreased 20%.
5. *__THREADED BAR__—the excellent cold-bending properties of Ledloy important here. Notice clear definition of thread and fine finish.
6. *__KNURLED STUD__—B-1113 originally used. Use of Ledloy resulted in 19.9% reduction in over-all costs, 54% increased in production.

*Company name and more detailed figures on request.

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By DONALD S. CLARK
Professor of Mechanical Engineering
California Institute of Technology, Pasadena

The Behavior of Metals Under Dynamic Loading*

THIS DISCUSSION of the behavior of metals under dynamic loading will be limited to the manner in which metals respond to stresses imposed in a short period of time as compared with the relatively long time that is involved in what is commonly referred to as static loading.†

It is not possible to establish exactly when a difference in the behavior of metals under static and dynamic loading was first recognized. By 1800 discussions of dynamic behavior began to appear in the literature. With the growth of railroads, the importance of the resistance of metals to dynamic loads became more apparent. During the past 150 years, engineers have been devising tests which might provide adequate comparisons to guide them in the selection of metals for installations subjected to dynamic loading.

During this period there has been much discussion on the meaning of these tests and ways to utilize the results in design. Most investigations have not provided information of a sufficiently fundamental nature to give an understanding of basic concepts concerning the behavior of metals under dynamic loading. In order that one may understand the mechanism by which metals deform under dynamic conditions, the experiments must be made as simple and as direct as possible without the complication of added variables. After the metal behavior is understood, the effect of such factors as shape, dimensions and stress concentration may be studied more intelligently.

IMPACT AND STRAIN PROPAGATION

In 1804, Thomas Young stated that an elastic deformation of a bar is transmitted at a velocity corresponding to the velocity of sound in the bar. For many years, it was not clear what would happen if the impact velocity were great enough to produce a strain in excess of the proportional limit of the metal. As a matter of fact, in the 1800's there was considerable uncertainty about the elastic limit and proportional limit. In 1941, von Kármán and Taylor each independently established the theory of plastic strain propagation in metals by considering the equation of motion of particles in the metal in relation to the stress-strain diagram. According to this concept, the velocity of propagation will be less than that of an elastic strain and can be expressed by the relation

$$c_p = \sqrt{\frac{\partial\sigma / \partial\epsilon}{\rho}}$$

* A Condensed presentation of the 1953 Edward DeMille Campbell Memorial Lecture presented before the annual meeting of the American Society for Metals in Cleveland, Oct. 21, 1953.

† A distinction between impact and rapid loading is important. In an impact type of loading, the inertia of the metal itself strongly influences the mode of deformation, while in rapid loading the load is applied more gradually, so that the inertia is not important.

Mathematics of Strain Propagation

where $\frac{\delta\sigma}{\delta\epsilon}$ is the slope of the engineering stress-strain relation at any given value of strain. Thus, the velocity of propagation, c, is a function of strain in the general case in which plastic as well as elastic strains are produced. The relation between impact velocity—the velocity at which the metal is set in motion at the point of loading—and the maximum strain produced is given by

$$V_1 = \int_0^{\epsilon_1} c\,\delta\epsilon$$

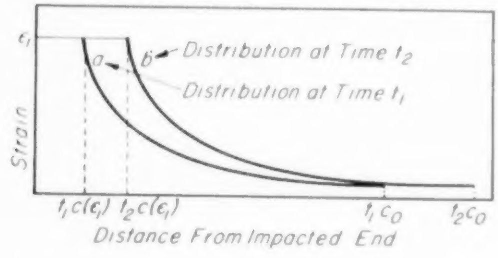
This relation indicates that an impact velocity, V_1, will produce a maximum strain, ϵ_1, which will propagate at a lower velocity than smaller strains. According to these formulas, the strain distribution in a very long bar struck by a mass traveling at velocity V_1 at two successive times, t_1 and t_2, after impact, is given as curves a and b, respectively, in Fig. 1.

The validity of this analysis was proved by Duwez in 1942 by experiments on long annealed copper wires. The agreement between theoretical and experimental strain distributions was, if not perfect, quite satisfactory, as shown in Fig. 2. In making the calculations, it was assumed that static stress-strain relations prevailed during dynamic loading. Although it had not been quantitatively established in 1942, indirect evidence indicated that the stress-strain relation was higher under dynamic conditions than under static conditions. A higher stress-strain relation would account for the difference between the calculated and the experimental strain distribution.

DYNAMIC STRESS-STRAIN RELATIONS

The most fundamental indication of the resistance of a metal to deformation is a stress-strain relation. But how does one obtain a

Fig. 1—Strain Distribution in a Rod Produced by Impact. c_0 represents velocity of propagation of elastic waves, and $c(\epsilon_1)$ represents velocity of propagation of plastic strain increment at a total strain of ϵ_1



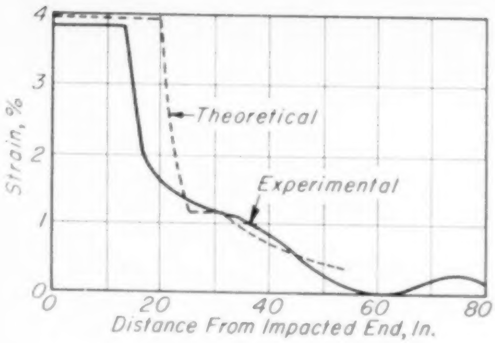


Fig. 2—Comparison of Experimental and Theoretical Strain Distribution for Annealed Copper in Tension. Impact velocity 62.5 ft. per sec.; duration of impact 1.3 millisec.

stress-strain relation during impact? Until recently, all attempts to obtain such relations have been disqualified because consideration was not given to the propagation phenomenon which prevails during impact. The tests have been made by measuring the force acting at one end of a specimen and the corresponding strain over some specified length of the specimen. In view of what has been said here about the propagation of strain, it should now be clear that the results of impact tests in which propagation effects are not taken into account will provide only average values and will not allow the establishment of the true relationship between stress and strain during the impact test.

Taylor and Wiffen made tests with small cylindrical specimens shot against heavy plates in which they took account of the inertia of the specimen in an approximate manner and found that the yield stress was increased above static values. Just this year J. D. Campbell conducted compression impact tests on long aluminum rods. Dynamic stress-strain relations for strains of the order of 0.006 in. per in. were obtained, the wave propagation phenomenon being taken into account in analyzing the results. The data drawn in Fig. 3 show a definite increase of the stress-strain curve by about 15 or 20% to higher values of stress for a given strain in the plastic region.

OTHER TENSION-IMPACT PROPERTIES

There are some significant dynamic properties of metals that may be obtained by means of the tensile impact test. For example, the maximum stress to which a metal may be subjected before failure occurs is greater under dynamic conditions than under static condi-

tions. This is illustrated in Table I. In tests on cold rolled low-carbon steel, the ultimate strength is 84,000 psi. statically and 105,000 psi. at impact velocities greater than about 25 ft. per sec. This is evidence of a higher stress-strain relation. Furthermore, most metals exhibit greater total elongation to failure under impact up to a certain impact velocity than under static loading, as illustrated in Table I.

A characteristic which may be of importance in some applications is the existence of a critical impact velocity of a metal. Referring to the expression given by von Kármán relating impact velocity to the amplitude of the strain wave ϵ_1,

$$V_1 = \int_0^{\epsilon_1} c\,d\epsilon$$

it is clear that there must be a maximum impact velocity corresponding to a tensile strain ϵ_m at which the slope of the engineering stress-strain curve is zero; that is, the strain at the ultimate tensile strength. Thus, the velocity of propagation of an increment of strain at ϵ_m is zero according to the relation

$$c = \sqrt{\frac{\dfrac{\delta\sigma}{\delta\epsilon}}{\rho}}$$

If an impact velocity greater than that corresponding to ϵ_m is applied to a rod in tension, the large plastic strains cannot propagate as fast as the end of the rod is being pulled, and fracture of the rod will occur immediately at the moving end, no energy being absorbed by the rod. Actually, the necking associated with tensile failures of ductile metals, which is not taken into account in the theory of wave propagation, occurs very near the impact end. Very little strain is propagated beyond the neck and the total elongation and energy absorption of the rod drop below the values obtained at lower impact velocities, although the failure is not completely brittle. The velocity at which this behavior occurs is called the critical impact velocity. An example of the effect of impact velocity on the total elongation of an S.A.E. 1020 cold rolled steel rod is shown in Fig. 4 on the next page. The critical velocity of 100 ft. per sec. is clearly indicated.

Some experimental determinations of the critical velocity have been made on several metals and checked with the values calculated from the static stress-strain diagram. Some of these comparisons shown in Table I are good, but not precise; the correlation would be better if a raised dynamic stress-strain relation were assumed rather than the static relation.

Fig. 3 — Static and Dynamic Stress-Strain Relations for Aluminum (J. D. Campbell)

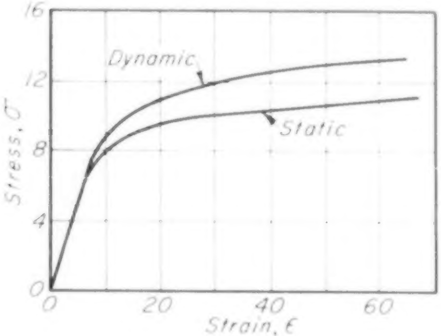


Table I—Static and Dynamic Tensile Properties

Material	Ultimate Strength, Psi.		Elongation in 8 In.		Critical Velocity	
	Static	Dynamic	Static	Dynamic*	Exp.	Theoret.
Ingot iron, annealed	37,100	57,400	25.7	16.2	100	†
S.A.E. 1015, annealed	50,600	63,500	28.0	30.0	100	†
S.A.E. 1022, cold rolled	84,000	105,000	6.0	15.0	100	95
S.A.E. 1040, annealed	78,050	91,800	20.4	20.7	> 200	†
S.A.E. 1045, quenched and tempered	142,900	169,000	5.7	9.2	190	88
S.A.E. 2345, quenched and tempered	145,250	175,250	8.4	14.1	> 200	161
S.A.E. 4140, quenched and tempered	134,250	151,000	8.5	14.7	175	132
S.A.E. 5150, quenched and tempered	139,000	148,100	8.5	13.3	170	159
Type 302 stainless steel	93,300	110,800	58.5	46.6	> 200	490
Copper, annealed	29,900	36,700	32.7	43.8	> 200	231
Copper, cold rolled	45,000	60,000	2.5	10.7	50	42
2S aluminum, annealed	11,600	15,400	23.0	30.0	> 200	176
2S aluminum, ½H	17,200	22,100	4.6	7.0	110	36
24S-T aluminum alloy	65,150	68,600	11.3	13.5	> 200	290
Magnesium alloy (Dow J)	43,750	51,360	9.6	10.9	> 200	303

*Maximum percentage elongation up to the critical velocity.

†Existence of a yield point prevents computation of critical velocity. Values are given in ft. per sec.

Time Delay in Yielding

The proportional limit increases with increasing strain rate until it coincides with the ultimate strength of the metal, as shown in Fig. 5 for a low-carbon steel. The ultimate strength increases until a strain rate of about 200 in. per in. per sec. is reached.

DELAY OF PLASTIC STRAIN

In 1904 Hopkinson observed that iron and copper wires subjected to rapidly applied tensile stress could be stressed much beyond the static elastic limit and even beyond their static breaking loads and still remain in the elastic range, provided that the time during which the stress exceeds the elastic limit is of the order of 0.001 sec. or less. Hopkinson found that an annealed iron wire having a static upper yield stress of 40,000 psi. could withstand a stress exceeding 75,000 psi. for a period of about 0.001 sec. without any appreciable permanent deformation. This was a highly significant observation, but apparently was overlooked by most investigators concerned with the study of dynamic properties. Hopkinson's experiment with iron is possibly even more significant because he did not observe yielding in the specimen when it was dynamically loaded and released for a sufficiently short time.

A more complete study of the delay of yielding in low-carbon steel was made in 1949 at California Institute of Technology. In this investigation, rapid-loading equipment was devised by which a predetermined stress could be applied to a specimen in a time as short as about 6 millisec. and maintained constant for as long as desired. The time of 6 millisec. to attain the desired load is large compared with the wave propagation times; therefore, propagation effects are not involved in studies with this equipment. Very careful determinations of stress and strain relations were made under static conditions to establish the static upper yield point of a low-carbon steel. Tests were then made in the rapid-loading equipment by impressing stresses in excess of the static upper yield point. It was observed that stresses above but near the static upper yield point could be maintained for a reasonably long time before the specimen yielded. The interval during which the stress was maintained constant before yielding has been called the delay time. By increasing the stress, the delay time before yielding decreased as shown in Fig. 6.

The lower limiting stresses represented by the horizontal portion of the curves for the higher temperatures coincide with the upper yield stress as determined by tests in which the load was applied very slowly. Delay time increases with decreasing temperature for a given stress. One would expect this behavior to be related to a thermal activation process, but so far such a relationship has not been established. Tests made at a temperature of −320° F. by Wood indicate that there is an upper limiting stress at which the delay time rapidly tends toward zero with increasing stress. In low-carbon steel, this limiting stress is of the order of 126,000 psi. Some of the specimens that were tested at this low temperature failed in a completely brittle manner. One might suspect that there is some relation between the maximum limiting stress and brittle fracture. However, completely brittle fractures were not exhibited by all specimens tested at the limiting

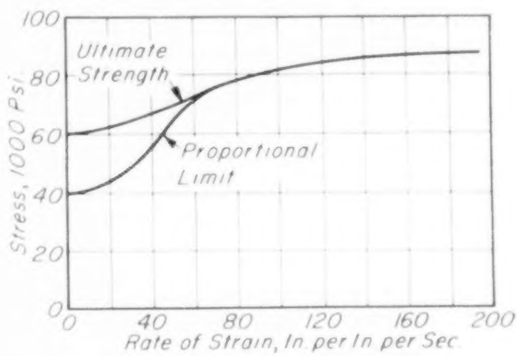
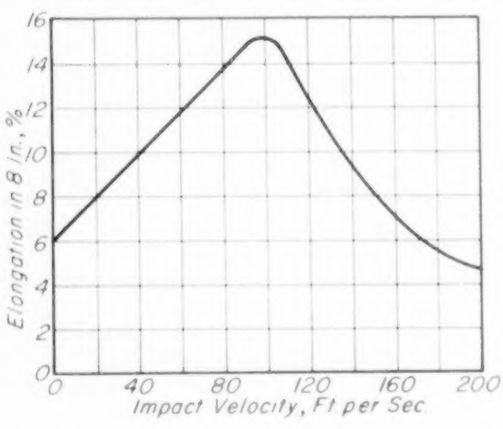


Fig. 5 – Effect of Strain Rate on the Proportional Limit and Ultimate Strength of a 0.22% Carbon Steel

Fig. 4 – Effect of Impact Velocity on Elongation of S.A.E. 1020 Steel, Cold Rolled



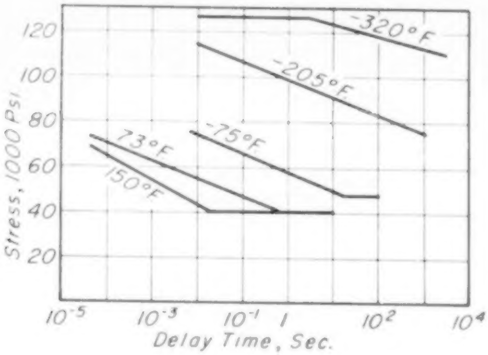


Fig. 6 – Delay Time for the Initiation of Yielding at Rapidly Applied Stresses in 0.17% Carbon Steel at Room Temperature

stress, and some of the specimens tested at slightly lower stresses did fail in a brittle manner.

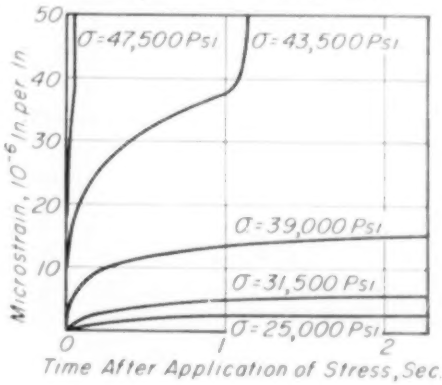
This discussion has been concerned with delay phenomena in a metal which exhibits a distinct yield point. What about the behavior of a metal for which the static stress-strain curve does not possess a discontinuity? Rapid-load tests have been made on such metals, including 18-8 stainless steel, normalized A.I.S.I. 4130 steel, quenched and tempered A.I.S.I. 4130 steel, 24 S-T aluminum alloy and 75 S-T aluminum alloy. The tests on these metals showed that plastic deformation occurs during the loading period and that a distinct delay time for yielding does not exist.

However, in the tests made on stainless steel subjected to a rapidly applied constant stress, the rates of strain are such that an appreciable time is required for the plastic strain to reach its equilibrium value as given by the static stress-strain curve. In a static test, a stress of about 42,000 psi. is required to produce a deformation of 0.4%. In a test in which the stress is rapidly raised to this same value and held constant, a strain of 0.4% is not attained until a time somewhat greater than 1 sec. has elapsed. This time effect was rather small in the other metals tested.

PREYIELD MICROSTRAIN

Vreeland recently studied the microstrain which occurred during the period of delay before yielding. The variation of this microstrain with time is shown in Fig. 7 for different constant stresses. The rate of strain is greatest at the beginning of constant load and decreases until a microstrain of about 30 x 10^{-6} in. per in. at stresses greater than approximately 40,000 psi. is present. After the strain has reached this order of magnitude, yielding occurs. Similar amounts of preyield microstrain have been observed by Roberts, Carruthers, and Averbach. This strain is of considerable importance in establishing a probable mechanism of the delay phenomenon which will be discussed further on.

Fig. 7 – Microstrain Vs. Time at Different Rapidly Applied Constant Stresses for a 0.12% Carbon Steel



Before the probable mechanism of time delay in yielding is discussed, the results of some other investigations that are pertinent to this study should be examined. The work of Low and Gensamer, Holden and Hollomon, and Schwartzbart and Low has shown that the presence of a yield point in the stress-strain diagram of iron or low-carbon steel is attributable to the presence of carbon and nitrogen. Some investigators have shown that the yield point is eliminated by the removal of practically all carbon and nitrogen.

Specimens treated in wet hydrogen to decrease the carbon and nitrogen content were subjected to rapid-load tests to determine the existence of any delay phenomenon. While the static stress-strain diagram did not exhibit a distinct yield point, the rapid-load tests did show a delay time and a distinct yielding. This behavior may be ascribed to the presence of a very small residual amount of carbon and nitrogen in the steel.

Recovery by Aging – An interesting series of tests was made to determine if the rapid loading of a low-carbon steel at a stress above the static upper yield point, for a period of less than the delay time at that stress, will have any effect on the time required for initiating yielding on a second application of the same stress.

The tests were made by rapidly loading a specimen of low-carbon steel to a stress in excess of the static yield point. This stress was maintained for a period approximately three-fifths of the normal delay time, so that yielding did not occur. The same specimen was again loaded rapidly to the same stress and the delay

Theory of Yield

time measured. In all cases, the specimens yielded on the second application of load in a time which made the total time at stress about equal to the delay time that would be required with only one application of load. Other tests were made in which the specimens were aged for different times at different temperatures during the period between stress applications.

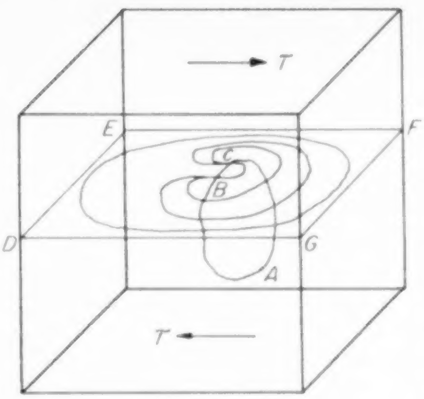


Fig. 8 – Frank-Read Dislocation Source

Results are shown in Fig. 9. Specimens that were aged for at least 100 min. at a temperature of 150 F. after each loading could be subjected successively to the rapidly applied stress without yielding, provided the time at load for each application was approximately three-fifths of the normal delay time. Aging at a temperature of 200 F. for at least 12 min. accomplished the same result. In other words, aging for the proper length of time at these temperatures apparently erased the effect of prior applications of stresses in excess of the static yield point. This means that some readjustment occurred in the structure during the aging treatment. From the two pairs of values of critical time and temperature of aging which were found to eliminate the effect of a previous stress pulse, an activation energy for the process of about 19 kg-cal. per mole was determined, which is just the activation energy for thermal diffusion of carbon and nitrogen in iron, within the accuracy of the data. Thus, the recovery of the material from the effects of short duration stress pulses represents another aspect of the yield phenomenon which is intimately related to the presence of carbon or nitrogen in the steel.

MECHANISM OF DELAY TIME

A theoretical explanation of the yield point in low-carbon steel in terms of dislocations and their interactions with interstitial atoms of carbon and nitrogen has been in process of development over the past several years. The phenomenon of delayed yielding, the microstrain which precedes yielding, and the recovery by low-temperature aging from the effects of stress pulses may be correlated with the theoretical developments – at least qualitatively. The theory depends upon three concepts.

The first, due to Cottrell, is that foreign atoms in solid solution form "atmospheres" around dislocations, and that such atmospheres tend to anchor the dislocations so that they are more difficult to move. A detailed theory of the manner in which dislocations may be released from atmospheres of foreign atoms under the combined action of an applied stress and thermal fluctuations has been presented by Cottrell and Bilby, who show that the thermal activation energy required for the release of a dislocation from an atmosphere decreases as the stress is increased. Thus, according to this theory, anchored dislocations will not begin to move immediately when a stress is applied but must wait for thermal fluctuations of sufficient magnitude before they can be released from their atmospheres of foreign atoms. It is clear that the mean time for such release decreases with increasing stress and with increasing temperature. It should be pointed out here for reasons which will become apparent later that the stress which is of importance is the local resolved shear stress in the slip plane and in the slip direction. This local stress may contain a contribution from other neighboring dislocations as well as the stress due to an externally applied load.

The second concept of importance to the present theory of the yield point in polycrystalline iron and low-carbon steel is that grain boundaries constitute relatively strong obstacles to the motion of dislocations previously released from anchoring atmospheres. That is, a considerably higher local stress is required to release a dislocation from a grain boundary or to cause a free dislocation to pass through a boundary than is required to release an isolated dislocation from an anchoring atmosphere. This concept was first put forward by Cottrell in 1950.

According to this view of the theory, when a load is applied to a specimen of annealed low-carbon steel, dislocations which are released from carbon and nitrogen atmospheres within the grains move freely to positions near the grain boundaries and are stopped there. As time goes on with the external load maintained, more and more dislocations are released

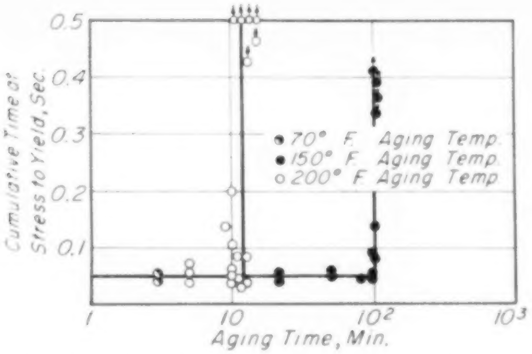


Fig. 9 — Effect of Aging Temperature and Time on the Time to Initiate Yielding at Constant Stress for a 0.12% Carbon Steel

within the grains and pile up against the boundaries. If at some point near a grain boundary enough dislocations accumulate, the resulting high local stress at the boundary reaches a critical value at which dislocations may be released from or pass through the grain boundary. This point in the process represents the initiation of macroscopic yielding.

The third concept of importance for the present dislocation mechanism of the yield point is the Frank-Read dislocation multiplication mechanism. This is a specific mechanism for the generation of many dislocations, all lying in a single slip plane, as shown in Fig. 8. A segment BC of a dislocation loop ABC lies in the active slip plane DEFG. The end points B and C of the segment are effectively fixed. When a shear stress of proper magnitude is applied, the segment BC will curve and generate new dislocation loops as indicated. When a new dislocation loop is formed, the original segment BC is re-formed.

A combination of these three concepts provides a dislocation model of an individual yield nucleus in annealed low-carbon steel. This model consists of a Frank-Read dislocation source with a saturated Cottrell atmosphere of carbon or nitrogen atoms or both which lies in a slip plane at some distance from a grain boundary or other obstacle to dislocation motion, such as a patch of cementite. The distance from the source to the obstacle is considered to be large, compared with the length of the Frank-Read source.

The behavior of such a yield nucleus under the influence of a rapidly applied constant resolved shear stress due to externally applied loads may be described qualitatively as follows: New dislocation loops are generated at the Frank-Read source and move rapidly out in the slip plane until they come to rest at positions in which they are in equilibrium under the combined action of the externally applied stress, the stress due to the obstacle, and the stresses produced by dislocation loops previously generated by the same source. As the number of dislocation loops accumulated in this way increases, the local stress at the obstacle increases, and the local stress at the Frank-Read source decreases. This effect follows from the nature of the stress fields of dislocation. Since the rate of generation of new dislocation loops is an increasing function of the local stress at the Frank-Read source, this rate decreases with time, following the application of the externally applied stress. If the applied stress is below the static upper yield stress, so that the obstacle does not break down as the dislocations accumulate, the generation of new dislocations eventually stops. However, if the stress is above the static upper yield stress, a sufficient number of dislocations will be formed to break through the obstruction, resulting in yielding.

Vreeland's preyield inelastic microstrains may be identified with the generation and motion of dislocations which accumulate in the yield nuclei prior to the onset of macroscopic yielding. It is evident from Fig. 7 that these preyield microstrains occur in a manner which is in good qualitative agreement with the dislocation model. The behavior of a material containing yield nuclei of the type postulated is also consistent with the measurements of the delay time for yielding and its dependence upon applied stress and temperature, as shown in Fig. 6. Finally, the mechanism explains the behavior of the material where it is subjected to short duration stress pulses above the static upper yield stress, and the recovery from the effects of such stress pulses by appropriate time-temperature aging treatments. The latter effect is due to the diffusion of carbon or nitrogen atoms, or both, to the dislocations generated during the previous stress pulse and the resulting stabilization of the array of dislocations.

The quantitative details of these theories are far more complicated than has been indicated here, but this discussion should be sufficient to indicate the progress that has been made in trying to explain certain phases of the dynamic behavior of metals. Eventually these theories will provide a working basis for the practicing design engineer.

Effect of Iron on Hardness, Bend Properties and Welding of Titanium Sheet

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THE TITANIUM sponge production process used by Du Pont yields metal containing small amounts of contaminants. The two more important are oxygen and nitrogen, which have been brought under improved control by basic engineering advances.

Another important residual element is iron, derived from the steel vessels used in the reduction of titanium tetrachloride with magnesium. While most of the titanium averages less than 0.25% iron, some with up to 0.5% is produced. Economics demands that this material be utilized.

It appears that iron, which stabilizes the beta phase, can be tolerated in two alloy categories, namely the alpha-beta and the beta alloys. Its effect upon alpha alloys has not been clearly established. Most of the wrought titanium sold to date, however, has been an oxygen-nitrogen-carbon alpha alloy containing up to 0.25% iron and having a nominal yield strength of 70,000 psi. This alloy has been designated by the various producers as RC-70 (Rem-Cru Titanium, Inc.), RS-70 (Republic Steel Corp.), Ti-100-A (Titanium Metal Corp.), and MST Grade III (Mallory-Sharon Titanium Corp.). We know of no instance wherein this alloy has been rejected

Table I – Composition and Constitution of Titanium Ingots

Designation*	N	C	Fe Actual	Fe Intended	O Actual	O Intended	Microstructure†
A-0.20	0.025	0.03	0.20	—	—	—	US + Mo-mo
A-0.44	0.02	0.03	0.44	0.50	—	—	US + Mo-mo
A-0.90	0.02	0.03	0.90	1.00	—	—	US + Mo-m1
B-0.53	0.03	0.035	0.53	—	—	—	US + Mo-mo
B-0.94	0.027	0.03	0.94	1.00	—	—	US + M1-m1
C-0.22	0.063	0.04	0.22	—	—	—	US + Mo-mo
C-0.54	0.075	0.03	0.54	0.50	—	—	US + Mo-mo
C-1.02	0.082	0.04	1.02	1.00	—	—	US + M1-m2
D-0.4-0.0	0.025	0.025	0.37	—	—	—	US + Mo-mo
D-0.4-0.15	0.03	0.035	0.40	—	0.15	0.10	US + Mo-mo
D-0.4-0.24	0.03	0.03	0.39	—	0.24	0.20	US + Mo-m1

*Letter indicates batch of sponge; first figure represents iron content; second figure (batch D) represents oxygen content.

†US = uniform A.S.T.M. grain size 8.

M = macrosegregation, m = microsegregation: 0 = none; 1 = light; 2 = medium.

Table II – Bend Tests in Terms of T★

Designation	Longitudinal	Transverse	Weld
A-0.200	1	1	1½
A-0.44	1¼	1¼	1½
A-0.90	2	2	2
B-0.53	1½	1½	1½
B-0.94	2	2	2
C-0.22	2	2	2
C-0.54	2	2	2
C-1.02	3½	4	3
D-0.4-0.0	1½	1½	2
D-0.4-0.15	2	2½	2
D-0.4-0.24	3	3½	3

★Samples are bent in V-die with 75° angle (see Fig. 2 on p. 76).

$T = \frac{\text{radius of bending die}}{\text{thickness of sheet}}$. Test is more severe as value of T decreases.

because of variable iron content, although some commercial shipments have averaged 0.3 to 0.4% iron.

In view of all these facts we initiated a research program on the effects of iron in the range of 0.25% to 0.5% on some common mechanical properties of titanium.

Four sponge batches were used for this investigation, and iron and oxygen additions were made synthetically. Compositions are shown in Table I. To facilitate tabulation, the sponge batches are ranged from A to D in order of increasing hardness. Batch D has high iron and was strengthened by oxygen addition. Batch C represents a high hardness batch modified with iron. Approximately equivalent mechanical properties were obtained for equivalent yield strength levels, which in turn cover the range for alpha alloys of commercial purity.

Hardness is plotted against iron content in Fig. 1, left. (Vickers hardness with 10-kg. load was taken perpendicular to the longitudinal cross section, micropolished.) Hardness change from 0.25% to 0.50% Fe is not very great, although there is an appreciable rise from 0.5% to 1% Fe. Reasons for this behavior are unknown. It will be noted that the slope of the lines from 0.5 to 1.0% Fe is independent of the hardness level of the original sponge. All of the alloys investigated exceed the solubility of iron in alpha titanium, and excess iron as beta spheroids was found by metallographic examination (see Fig. 3, 4 and 5).

Rolling and annealing cycles were held approximately constant, to simulate commercial rolling practice and to perform the hot work in a constant region of the alpha-beta field of the Ti-Fe phase diagram.

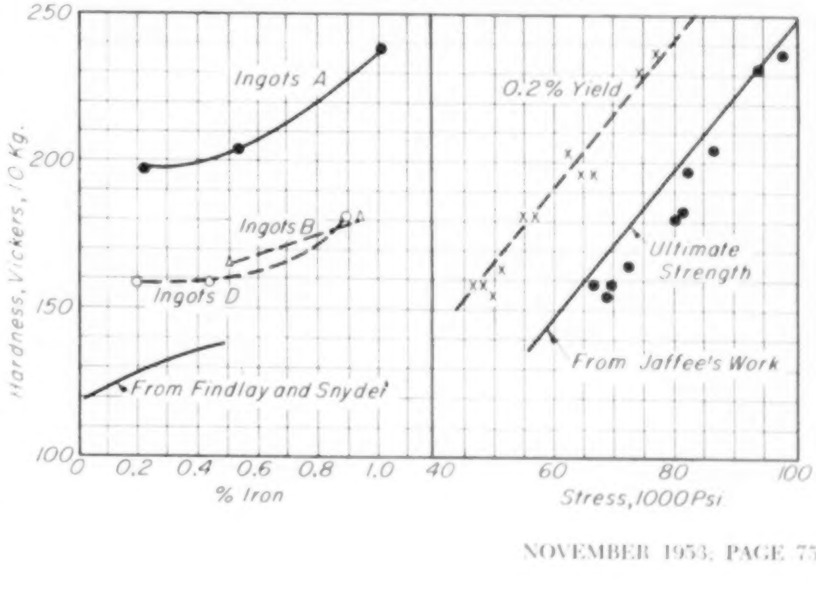
Data previously reported by Finlay and Snyder in *Journal of Metals*, for February, 1950 are included in Fig. 1 to show the slow change in hardness with iron content of iodide titanium.

Tensile properties also correlate with hardness as shown in Fig. 1 at right. The correlation obtained is closely associated with the straight line for ultimate strength established by Jaffee, Ogden and Maykuth (*Journal of Metals*, October, 1950).

The strength shows a marked increase as the iron goes up from 0.50 to 1.0%, while the elongations indicate that the ductility of the laboratory-produced material is equivalent to commercially produced sheet.

Commercial bend specifications as related to yield strength are generally met up to 1% iron. As shown in Table II, iron at the 0.5% level has no apparent effect on sheet directionality and weld bend quality. A representative series of bends is shown in Fig. 2.

Fig. 1 Relation of Hardness to Iron Content and to Strength Factors of Titanium Sheet



Structure–The microstructures are illustrated in Fig. 3, 4 and 5. All the material was fine grained, having an equi-axed alpha structure with dispersed beta spheroids. As is seen in Table I on p. 74, pronounced segregation was observed only in the sample designated C-1.02 containing 1% iron.

Figures 4 and 5 indicate that the ½% and 1% iron alloys may be considered as alpha-beta alloys. There is a major difference, however, between these and one such as the 8% Mn alloy designated RC-130-A and RS-120. The latter, in hot rolled condition, consists of alpha islands in a beta matrix, whereas our ½ and 1% iron alloys consist of beta islands in an alpha matrix. Presumably, then, the low-iron alloys would behave essentially as alpha alloys and would exhibit superior high-temperature strength and creep properties.

Aging–During this investigation some weld bead hardening from air cooling was observed in the welds made for bending tests. This had already been reported in the literature. Hardening indicates an unstable condition and a possibility of embrittlement by aging at service temperatures. While the former work did not show any marked aging of metal containing less than 1% iron, we made some tests on 0.5% iron sheet to clear up this point.

Welded samples were aged, since the welding of 1/16-in. sheet represents the most drastic heat treatment encountered during the fabrication of titanium. There was no change in weld ductility as measured by the bend test after aging from 2 to 32 hr. at 400° C. (725° F.) and 230° C. (446° F.). These periods were used since the other investigations had shown age hardening for similar intervals in quenched beta titanium, higher in iron. We also found no change in the weld hardness after aging.

EXPERIMENTAL PROCEDURE

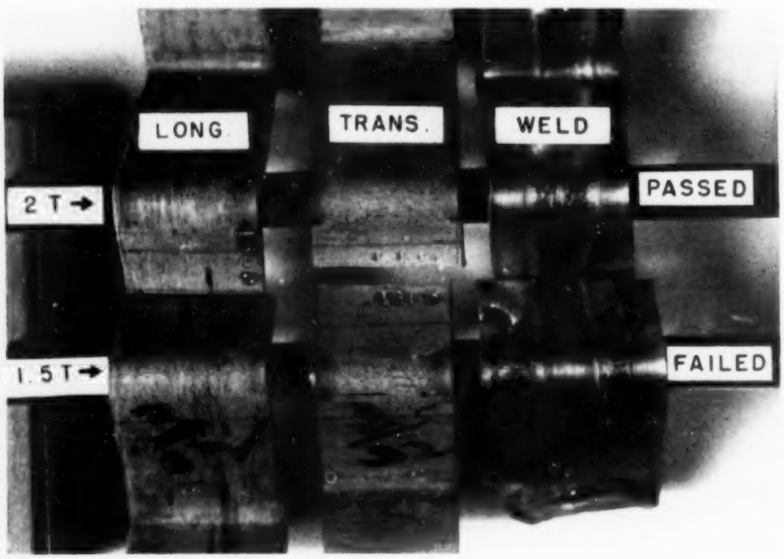
It may be of interest to describe briefly our experimental procedure:

Two-pound arc-melted ingots were prepared. These ingots contained from 0.20% to 1.00% iron as shown in Table I, any iron additions being made directly to the charge in the form of a titanium-iron master alloy prepared from National Bureau of Standards' 55C iron powder. The ingots were subsequently sectioned to produce rectangular slabs (2½x2½x1 in.) for rolling. Hot reduction, starting at 1425° F., in 10 to 12 passes in rapid succession, with no cross-rolling, on a 10-in. two-high mill, resulted in 16-gage (0.060-in.) sheet for test purposes. These sheets were air annealed at 1425° F. for 20 min. and air cooled. Test coupons were obtained from all parts of the sheets. Weld and hardness samples were descaled by belt grinding. Sheet bend and tensile samples were tested without descaling.

The sheet produced was from 30 to 35 in. long by 2½ in. wide. Longitudinal micro samples were taken from each end and the center. Segregation was rather uniform along the length (Table I).

Vickers hardness was determined at three locations and found to be uniform, indicating good distribution of alloying elements. Ingots A had maximum variation of 2 Vickers numbers.

Fig. 2–Representative 75° Bend Tests on 1/16-In. Sheet From Ingot A-0.90, Showing Uniformity of Longitudinal, Transverse, and As-Welded Bends. Longitudinal and transverse samples have surfaces as rolled. Longitudinal properties of this sheet are: 0.2% yield strength, 55,000 psi.; ultimate tensile strength, 80,000 psi.; elongation in 2 in., 25%; hardness of sheet surface, Rockwell G-66; hardness of sheet cross section, 182 Vickers 10-kg



end to center to end; ingots B, 6 numbers, ingots C, 5 numbers, and ingots D, 8 numbers —the hardest ones with the highest amount of impurities generally having the largest variation. We noted that the samples with largest hardness spread had the most segregation, as reported in Table 1.

Grain size was essentially uniform throughout in all sheets.

The experimental weld beads were deposited in a small inert-atmosphere arc furnace. Weld conditions were: arc travel 6 to 8 in. per min., 40 to 50 amp., 20 to 30 volts, d-c, straight polarity and a 3/32-in. electrode. To determine the reliability of the furnace two weld beads were remelted; hardness and bending tests were substantially unchanged, even after the second remelt. Consequently, air contamination in the furnace was virtually nonexistent and the weld bead hardening therefore resulted from quenching.

CONCLUSIONS

Based upon the data developed, we conclude that 0.5% iron has little effect on the room-temperature mechanical properties of commercial-purity alpha alloys such as RC-70, RS-70, Ti-100-A and MST Grade III, in the range of 55,000 to 70,000-psi. yield strength. Data have been presented which demonstrate that laboratory-produced sheet of variable iron content generally complies with commercial sheet specifications. Very little directionality was observed in the sheet bend test, and weld bend and sheet bend values are equivalent.

Iron contents were investigated up to 1% to obtain practical limitations. The addition of 1% iron had a pronounced strengthening effect, although sheet and weld bend quality remained generally satisfactory.

Aging studies on commercial purity alloys containing 0.5% iron showed stability, as-welded, at service temperatures ranging up to 400° C. (752° F.).

No high-temperature data such as creep or stress-rupture were obtained. Published work by other investigators indicates that the effect of an additional 0.25% to normal iron contents (or a total of 0.5%) would have negligible effect on the creep characteristics.

Equi-Axed, Wrought Alpha Grains With Dispersed Beta Spheroids. Etched with HNO_3 and HF, 250 ×. Beta within grains and at boundaries, but not segregated, in ingot with 0.54% Fe; 1.02% Fe gives more beta grains and medium segregation

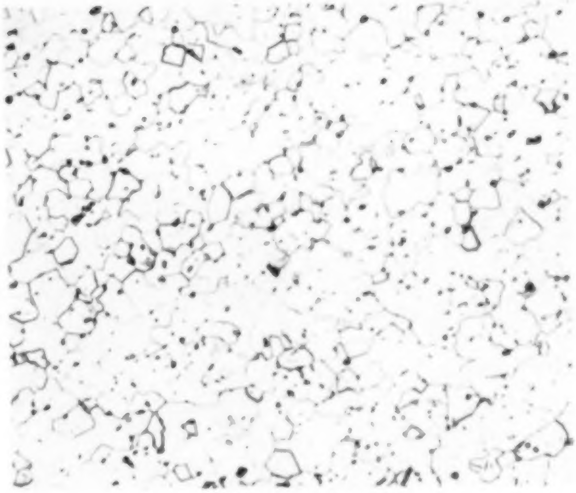


Fig. 3—Ingot C-0.22

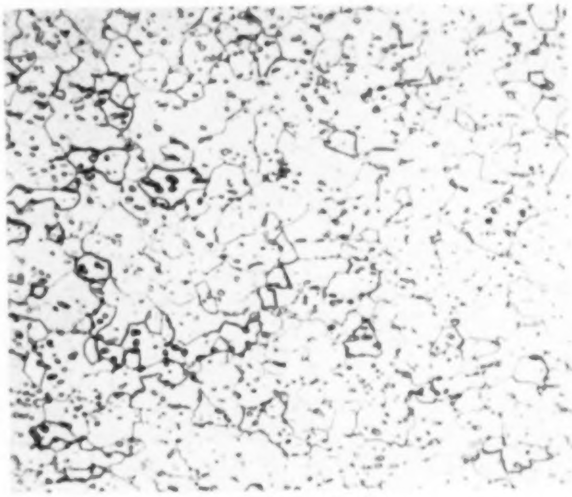


Fig. 4—Ingot C-0.54

Fig. 5—Ingot C-1.02

Irwin Cameron Mackie

An Eminent Canadian Metallurgist

Of those who have served their day and generation through the medium of their chosen profession, the name of Cameron Mackie ("Cam" to his associates) is outstanding.

In these days of ever increasing speed, safety assumes growing importance. Particularly is this so in the matter of rail transportation.

Years ago—in 1911 or thereabouts—a fatal derailment on the Lehigh Valley Railroad—broke one rail (in track only ten months) into 27 pieces! This focused attention of the U. S. Interstate Commerce Commission on a matter that had troubled railroad and railmill men greatly as weights of rails and speed of heavy engines kept increasing. The best of the rails were seemingly unable to take the punishment.

One very common type of fracture evidently started from an internal defect, in the central zone of the rail head. These cracks were so common they acquired a name—"shatter cracks" or "internal transverse fissures". One faction held that such cracks developed in originally sound rails, and were due to service stresses of too great a magnitude, but in 1919 two metallurgists with the Pennsylvania Railroad (F. M. Waring and K. E. Hofammann) found what seemed to be shatter cracks in new rails never laid in track. The alleged cracks were disclosed by etching sections cut from the center zone of the railhead. Railmakers for some time refused to admit the existence of cracks in new rails. They attributed the cracks to the effect of strong, hot acid on such hard steel containing internal stresses of considerable intensity. The acid *produced* the cracks, it was maintained, instead of revealing a defect as alleged. It did not take long, however, for impartial investigators to prove the existence of real cracks in many newly rolled rails.

Certain eminent metallurgists who studied the cracks in new rails were emphatic in asserting that they were formed while the rails were red hot—in fact above the critical temperature—this judgment being based on the paths of the cracks in relation to the microstructure.

After it was experimentally proven that samples cut from rails at the rolling temperature, and buried in lime for slow cooling, were invariably free from shatter cracks even when the corresponding rail, naturally cooled, contained many cracks, nothing was done about it because such slow cooling softened the rails unduly. This was thought to be unavoidable because of the accepted opinion that the cracks formed above the critical temperature.

This generally accepted theory as to the birth of the defects failed to convince Cam Mackie. By a series of tests which, in retrospect, look extremely simple, he discovered that the cracking occurred at a comparatively low temperature, long after the rails had hardened in cooling and had lost their red heat. It remained only to accumulate a sufficient amount of evidence with the various sized rails, to fix the temperature zone in which retarded cooling was required and the degree of retardation necessary to eliminate the shatter cracks. Finally Mackie found that if some 100 rails were placed in a suitable iron box while they were at a temperature between 660 and 930° F. and kept there about 15 hr. until cooled to 200° F. and then removed, these rails were free from shatter cracks. (Hydrogen in solid solution at high temperature was found later to be the culprit. Given time during slow cooling, this gas could diffuse out of the steel without building up damaging internal stresses.) Hundreds of tests were made, half being treated and half not, with the result that, at the end of two years he could confidently report his findings to the railroads and get them to put treated and untreated rails into tracks for comparative tests.

The retarded cooling process as developed by Mackie at the works of the Dominion Steel and Coal Corp. in Sydney, Novia Scotia, was patented in Canada in 1932 and in many other countries. For many years now practically all rails rolled in the United States and Canada have been "control cooled" as the present phrase goes, and the results in service have confirmed the original belief of the inventor that rail failures would be vastly reduced by the elimination of shatter cracks.

What of the man responsible for all this?

Cameron Mackie was born in Prince Edward Island on Nov. 14, 1880. While he was still a boy his parents moved to Brockton, Mass., where he graduated from high school. He returned to Canada and entered Dalhousie University, Halifax, his studies being about equally divided between science and the classics. He obtained his B. A. (magna cum laude) in 1901.

For the first year after graduation Cam Mackie taught school but soon heard of an opportunity that was available in the chemical laboratory of the Dominion Steel and Coal Corp. in Sydney. So it is that in July of 1953 he passed his 51st anniversary with the one corporation, serving successively as chemist, metallurgist, and finally as director of metallurgy and research.

Cam Mackie still puts in a full day's work and is to be found in whatever part of the huge works any metallurgical problem has appeared. His staff speaks of him as an inspiring leader and one for whom it is a pleasure to work. Like

many another clever man, Mackie is quiet and retiring by nature. A year or so ago he was offered a Doctor of Engineering degree, Honoris Causa, by Nova Scotia Technical College, but preferred to remain plain Cam Mackie.

He ardently wishes that the present day's crop of metallurgists and scientists training in the universities would take a good dose of classics as part of their training. He feels that it would enable them to write letters and reports that would not require clairvoyance for interpretation.

Cam Mackie has always been interested in sports, following his former activity in football and tennis. In recent years it is curling in the winter and golf in the summer. Lest the subject of this sketch should be thought to be unusual, it should be noted that his golf is erratic, a mixture of pars and double-figure holes.

"I am a bit of a heretic," he says, "but I still support the Church in the perennial hope that it will get into the present century." Especially is he interested in Y.M.C.A. in a realistic and very generous manner. His royalties on rails have never caused him to alter in any way his former manner of living. He is not known as a public speaker but will be found the center of entertainment in any friendly gathering, with his original thinking and ready wit.

Cameron Mackie has been awarded the platinum medal of the Canadian Institute of Mining and Metallurgy in recognition of his metallurgical contributions. He also has the certificate of the American Society for Metals, recognizing his membership in the society for the past 25 years. This certificate and an ordinary calendar are the sole adornment of his plain but roomy office. HAROLD J. ROAST

The Open-Circuit Thermocouple

A Neglected Device of Considerable Adaptability

By RICHARD D. POTTER
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Research Department
U.S. Naval Ordnance Test Station, Inyokern
China Lake, Calif.

IN MANY PROBLEMS where temperatures must be accurately known it is frequently convenient to spot-weld the thermocouple wires to the metal in such a way as to make the sample under study act as a part of the hot junction of the thermocouple. The method indicates the true temperature of the material and is particularly useful for rapid temperature changes and small sample size.

Phase reactions in a metallic alloy under equilibrium (or quasi-equilibrium) conditions are commonly studied by so-called heating or cooling curves. The elementary metallurgical laboratory experiments have been greatly refined for precise work by physical metallurgists, but usually a fused-junction thermocouple is relied upon to indicate the temperature changes of the material under study. When temperature is plotted against time during heating, a smooth curve will result except when some exothermic reaction occurs in the body under study whereupon the time-temperature curve is displaced in the direction of a higher heating rate (and vice versa for an endothermic change). In this technique a fairly large amount of sample material is necessary to produce enough heat change from a phase reaction to affect the normal heating and cooling rates. Sometimes thermopiles and differential thermocouples are used to amplify the thermocouple output or to compare the temperature of the sample and an adjoining metal known to have no phase change to exaggerate the heat variances. However, these usual methods for following reactions during fast heating and cooling result in less and less sharp indications so that it becomes difficult and sometimes impossible to pick out the actual phase reaction point.

When standardizing high-temperature ther-

mocouples, the writer and others have replaced the usual fused junction with a small piece of high-purity metal whose true melting point is known. The individual wires of the thermocouple are joined to the ends of the insert and the junction thus formed is placed in a uniform heating chamber. The thermocouple output is observed until melting occurs. Such melting of the junction gives a very sharp end-point on the e.m.f. output and a calibration point is obtained.

To distinguish this device, the author refers to it as an "open-circuit" thermocouple.

Extending this technique to studies of reaction in the solid state, the individual wires of the thermocouple are spot welded to a small piece of the material under scrutiny. The validity of such a device is supported by the theories of thermo-electric phenomena in consideration of the presence of a third dissimilar metal in a thermocouple circuit. When the third dissimilar metal is the sample, as in the open-circuit thermocouple, the temperature indicated by the thermocouple circuit is a function of the temperature at the two spot welded junctions; therefore, it is necessary to have the two junctions at the same temperature. The open-circuit thermocouple will not indicate temperature variations of the material between the spot welded junctions unless such variations include the area of the junctions. For correct usage the entire sample between junctions, and also the junctions, must be at the same temperature.

When the size of the sample is kept small, its true temperatures are obtained by observing the thermocouple output during heating or cooling. Actually, the size of the sample should be immaterial if the temperature is reasonably uniform throughout the specimen, but since most such investigations are done while the sample is heated by radiation or conduction, a large sample may result in fairly large temperature differences. If fast heating rates and fast cooling rates are involved, one is usually forced to use small-sized samples. The reaction heat is then correspondingly small—sometimes too small to be clearly indicated with the regular fused-junction thermocouple placed alongside or attached to the sample.

However, with the open-circuit thermocouple substituted for the usual fused-junction type, phase change reactions have been determined in a large number of materials and at temperatures ranging from −40 to 1000° C. (−40 to 1830° F.) and there is no reason why the temperature range cannot be extended. Sample size has varied from ⅛-in. cubes to ½-in. diameter rods 2 in. long and 1/16-in. disks up to ½ in. in diameter. Generally the open-circuit thermocouple was joined to the sample with a maximum of distance (on the surface) between the two junctions so there was no criterion of inter-wire spacing. The wires were usually spot welded to the surface of the sample. (For comparison, a regular fused-junction thermocouple was often inserted into a hole in the sample.)

During some tests, heating rates up to 170° C. (300° F.) per min. were used; however, most of the tests were made at heating rates of about 10° C. (18° F.) per min. in order to standardize the technique. Cooling rates have not been critically determined, but the austenite-to-martensite transformation has been indicated.

Other work by the author has utilized the open-circuit thermocouple in phase reaction studies at heating rates up to 260° C. (470° F.) and cooling rates to 420° C. (750° F.) per min.

The open-circuit thermocouple also has been used by the author to determine the melting points of certain fusible alloys. The maximum liquidus temperature in which this technique has been used so far is about 300° C. (575° F.). In these tests the bare thermocouple wires were held parallel, ⅛ in. to 1 in. apart, and were inserted from ⅛ to 4 in. into the liquid so that direct physical contact was made between wire and liquid alloy. Liquidus temperatures and some solid state reactions were recorded—usually with exaggeration of the phase break. With the deeper submersions the crucibles were not under uniform temperature and small discrepancies were noticed. However, phase reactions were recorded which occurred in the lower half of the melt due to monotectic reactions and double liquid separation. It is not clear yet if they were picked up by the wires in the lower liquid (or solid) or if the heat effect was conducted through the upper liquid (or solid) to the surface contacts of the thermocouple; the latter is probably correct, but even then one merely needs to insulate the wires from the surface contact and place the open-circuit wires in such a way as to minimize conduction losses.

Other Possibilities—It seems possible to extend this technique to the measurement of temperature and high-speed temperature changes of materials and machines. The operating surface temperatures of parts could be measured rather easily without disturbing the continuity or contour of the section, and since the method determines the actual temperature without requiring heat transfer by conduction to a second body, results should be more accurate.

Ten Practical Uses of Statistical Quality Control in Metallurgical Plants*

THIS THIRD contribution to the Philadelphia Chapter's series on "Practical Applications of Statistics in Laboratory and Production" must necessarily be limited — by virtue of a desire to speak from personal knowledge — to data from Aluminum Co. of America's operations. It will be slanted toward the application of statistics to production of aluminum stock for sale to intelligent purchasers. It will bear stating at the very outset that uniform quality, high enough to meet the requirements of use at the lowest possible cost, is the objective of such a control program.

No one should conclude that statistics are a substitute for quality control. Statistical analysis is a very valuable tool in the hands of a competent quality control man, just as a slide rule is useful to an engineer. Neither statistics nor a slide rule, however, is a substitute for integrity, sound metallurgical thinking, and technical skill in the control of quality of products in the metallurgical industry.

Quality of the final product — say an aluminum disk — starts clear back with the raw materials, such as the bauxite ore. Control through the ore refining and smelting steps centers on composition as determined by chemical analysis. Alcoa's operations include fabrication of various useful forms, ranging from castings to wire, forgings to paint.

Obviously the control of quality of these items involves not only composition but also mechanical properties, dimensions, internal quality, surface quality, and various particular characteristics required by specific uses.

General Organization — Quality control begins when the salesman gets the order or arranges for a price estimate. He must record a complete description of what the customer wants and applicable specifications (if any).

Each customer and Government specification is submitted to the specification department of the metallurgical division, Pittsburgh, for careful scrutiny. Its responsibility is to approve all specifications or to note exceptions to any requirements with which Alcoa products do not comply. The sales and manufacturing groups are notified of any exceptions.

A "Quality Requirement Record", as reproduced in Fig. 1, may be used where a description of the customer's operations and use requirements will result in a clearer understanding of the quality required for sheet products. Before filling special orders the manufacturing plant also makes a "Special Practice Record", which is sent to the quality standards department of the metallurgical division, Pittsburgh. This department scrutinizes the Quality Requirement and Special Practice Records as to all technical matters and distributes approved copies to all responsible personnel in the Alcoa plants that may be called upon to manufacture the items in question.

Standard manufacturing practices, covering the details of all processes, are recorded by the Works' metallurgical departments. These records are coordinated for all plants by the metallurgical division, Pittsburgh. It is the responsibility of the metallurgical department for each manufacturing division to maintain

*Report of a Lecture by John W. Hood, Head, Quality Standards Department, Metallurgical Division, Aluminum Co. of America, Pittsburgh. Given before the Philadelphia Chapter, American Society for Metals, March 25, 1952.

uniformity in practices between the plants manufacturing identical products, within the limitations in equipment available at each plant. Control limits in composition, mechanical properties and other characteristics are maintained by the metallurgical division, Pittsburgh, and are used as a guide for quality control by the various plants.

Let us, in the interest of brevity, confine our attention to the use of statistics in the control of quality in such manufactured objects. Each manufacturing works has, in its organization, at least one man trained in the application of statistics to quality control, and the use of statistics in each plant is coordinated by a member of the metallurgical division, Pittsburgh. Experience has shown, however, that statistical quality control cannot be applied universally. For example, the brightness of aluminum sheet is important to some customers and is evaluated primarily from the standpoint of appearance, rather than by a measurable standard. Therefore, statistics are not applicable.

Presented herewith are ten categories in which statistical control has practical uses.

TEN PRACTICAL USES

1. Quality Assurance – The preceding highly informative papers in this series by Dr. Youden and Professor Burr have given an idea of the mathematical basis of the subject. They have stressed the fact that successive objects in mass production actually do vary; also that the measurements themselves have inherent variations. Information has been given in these papers on the units for measuring this variation, and means whereby one can estimate whether the variation is "normal" or "out of control".

Important manufacturing variables in an aluminum product – for example, a strong aluminum alloy sheet – are composition of the alloy, temperature and time of solution heat treatment, speed of quench, intermediate heating operations, amount of cold work, and grain structure. This is a rather formidable list, but Fig. 2 shows the net result of control of the many variables in manufacturing a specific class of sheet. The solid curve shows the distribution of the approximately 40,000 actual mechanical property test results of the product as manufactured at several Alcoa plants during 1936 to 1940. The small circles show the distribution of some 20,000 tests representing the product as supplied in 1940 and 1941. Although

Fig. 1 – Representative Record to Be Prepared by Salesman as an Aid to Manufacturing Works' Understanding of Quality Requirements of Sheet

QUALITY REQUIREMENT RECORD
Sheet Products

Date Issued ______ Record No ______
Alcoa Product ______ Customer ______
End Product ______ Address ______

Order No ______ Item No ______ Date Order Entry ______

Description of Alcoa Product:

USE INFORMATION

End product will retain original - Thickness ☐ Length ☐ Finish ☐ Width ☐ Diameter ☐
Chief Use: Structural ☐ Ornamental ☐ Utility ☐

Customer will perform following operations:

Cutting	Working	Joining	Finishing
Blank ☐	Bend ☐	Braze ☐	Anodize ☐
Machine ☐	Brake Form ☐	Weld	Clean ☐
Rout ☐	Press Form ☐	Spot ☐	Etch-Acid ☐
Saw ☐	Draw ☐	Butt ☐	Etch-Caustic ☐
Shear ☐	Forge ☐	Torch ☐	Paint ☐
Slit ☐	Roll Form ☐	Rivet ☐	Polish ☐
______ ☐	Spin ☐	______ ☐	Scratch Brush ☐
______ ☐	______ ☐	______ ☐	Finish only One Side ☐

Important quality factors for product as supplied:

Measurable	Metallurgical	Visible
Diameter ☐	Deep Drawing ☐	Flatness ☐
Length ☐	Freedom from Ears ☐	Freedom from Oil ☐
Squareness ☐	Workability ☐	Freedom from Oil Stains ☐
Straightness ☐	______ ☐	Brightness ☐
Thickness ☐	______ ☐	Smoothness of Edges ☐
Width ☐		Uniform Appearance ☐
______ ☐		Smoothness of Surface ☐

Require only One Good Side ☐ Identify Good Side ☐

Remarks:

Data Supplied by ______
7-24-46 Drawing Attached ☐ Remarks on Opposite Side ☐

Composition Control

every piece of sheet was not tested, it is obvious that the process variables were controlled within essentially the same ranges during the two periods. As a result, the product can be used with confidence.

This represents, then, an example of one of the valuable uses of the tool known as statistical quality control – namely, assurance that the product has certain desirable characteristics.

II. Operator interest is a second valuable use of this tool. The need for controlling alloy composition within prescribed limits has been mentioned. This involves not only the use of alloy and pig charges of known composition and in the right quantities, but also the proper mixing and blending of the materials in the molten state. For this important task, dependence is placed upon the furnace operator, and the quality of his performance is checked by chemical analyses of samples taken at regular intervals from the melt. These analyses are of major importance since the ingot or ingots cast at the time are held in bond, so to speak, until the chemistry is approved as being within the required specification limits. No analysis of slabs or finished sheet or shapes is made during fabrication.

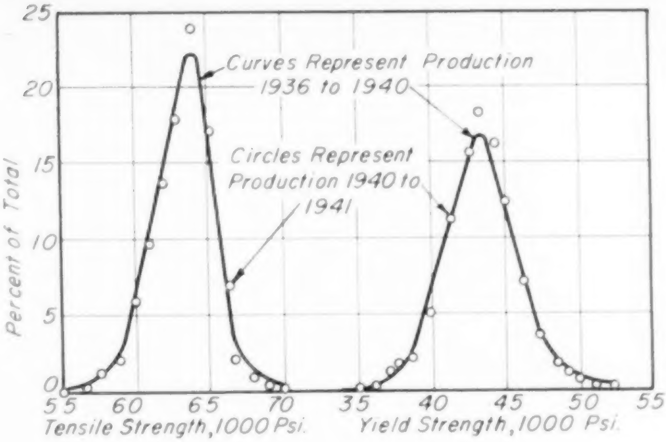


Fig. 2 – Lines Show the Frequency Distribution of Some 40,000 Inspection Tests on a Specific Class of Aluminum Alloy Sheet Made in 1936 to 1940. Circles represent similar results for the next two years; their location close to the lines is assurance that all process variables remained within the formerly established ranges

If the analysis of any sample goes out of control limits, action is taken to determine the cause and correct it. It has been demonstrated that placing control charts *at the furnace* in view of the operator, results in more accurate performance. By seeing the results of his work, he not only is given a sense of pride in keeping the composition within the limits, but also is able to see when a minor letup in his efforts causes a slight deviation, even though it still may be within limits.

In other words, everyone likes to see the results of his work and takes a more active interest in doing it right if he

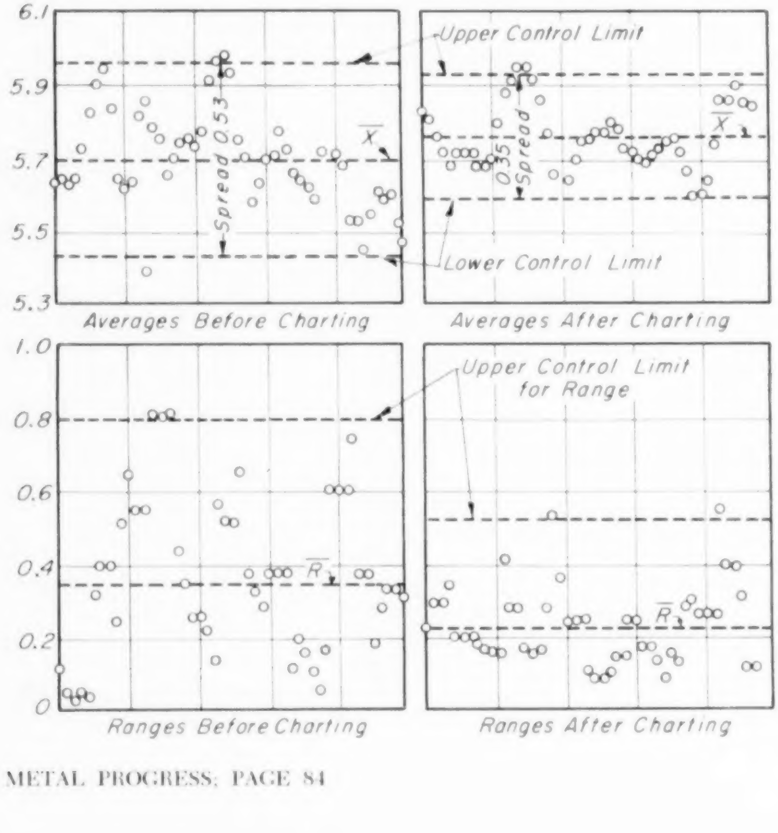


Fig. 3 — Chemical Analysis of Furnace Product Is Under Closer Control (as at Right) When Test Results Are Posted at the Furnace so Operator Can Watch His Own Performance.

is made a part of the team. Statistical control charts help accomplish this important result. Figure 3 represents an actual case; note the closer control limits applicable after charting.

III. Basis for Decisions – There is the story about the apple grower who hired a man to count apples for him. After the counter had been at the job and very happy doing it for some time, the boss asked him to start separating the good ones from the bad ones. After a short time at this job, the formerly happy apple counter became very unhappy and his health began to fail. His troubles stemmed from the mental strain of having to make all those tough decisions!

It is a fact that most people do not enjoy making decisions. While baseball fans like to razz the umpire, very few want to swap places with him. This introduces a third valuable use of the tool, statistical quality control – namely, that of providing definite rules on which to base decisions.

Alcoa manufactures great quantities of "circles" which are actually disks blanked from sheet stock. They are used for making cooking utensils, cans, lids, and so on. Until about five years ago, each one of these circles was inspected individually and there were literally millions of them. It was called "100% inspection". It is known, now, as it was suspected then, that 100% inspection is impossible because of the monotony of the task, the fatigue factor, and the fallibility of human nature.

To solve this problem, a sampling plan was selected from the so-called Dodge and Romig tables worked out by mathematicians for the inspection of parts for telephone apparatus. The specified number of circles is selected at random from each manufacturing lot, as prescribed by the tables, and each disk in this sample is carefully inspected. If the quality of the sample meets the predetermined standard, the lot is passed without further inspection. If the sample fails, the lot is set aside for detailed inspection of each piece. While the need for decision remains, the number of decisions required has been reduced by a tremendous margin.

Damage from excessive handling of the product has been minimized. Furthermore, the inspector has more opportunity to call on his superior for help in the doubtful cases. Figure 4 shows this inspection operation. It insures that the average outgoing quality level is as required; obviously, it does not prevent the occasional shipment of defective pieces, but neither did 100% inspection.*

Inspecting Blanked Disks

IV. Incentive to earn low inspection cost is also illustrated by the above instance. Operating management can earn low inspection costs without risking any reduction in the quality of the product shipped. A daily record of the number of lots requiring 100% inspection (or "detailing") is prepared. The cost of this inspection is, of course, greater than for those lots which are passed on the basis of a sample only. If the number of lots requiring detailing goes up, those in charge have an immediate incentive to correct the cause. Furthermore, there is less tendency to blame high scrap on what the inspector had for breakfast. Thus, sample inspection has enabled the operating management to *earn* low inspection costs by keeping the quality up.

V. Establishment of Customer's Standards – The aluminum industry, as is true of others in the metallurgical field, has a great many customers which manufacture a wide variety of products for different uses. There is considerable difference in the quality standards required for aircraft sheet as compared with roofing sheet, architectural spandrels as compared with engine pistons, railroad car structural extrusions as compared with kitchen trim, and beer barrels as compared with toothpaste tubes. However, each use has definite quality standards.

Take, for example, aluminum collapsible tubes used for packaging toothpaste, cosmetics, and all sorts of thickened fluids. Figure 5 shows a control chart set up to record wall thickness to the requirements of a certain use. It would be a hopeless task to inspect each tube for wall thickness. However, by agreement with the customer, this dimension is controlled within

*In the discussion, after this lecture had been presented in Philadelphia, Mr. Hood was asked whether there were circumstances when 100% inspection would be necessary. His reply was:

"The requirements of the next operation or of the final service determine the type of inspection required. Where a statistical sampling plan is applied, the desired quality level is assured mathematically. There is evidence that there is a greater chance for defectives being accepted, particularly in borderline cases, with 100% inspection than with a sampling plan. However, some very critical items should have 200, 300, and even 400% inspection. Of course, this applies usually to finished items whose failure in service would involve grave risk.

"All items in a lot which have been rejected in a sampling plan are inspected. This 100% inspection is in the nature of a salvage operation, since it is known that such a lot contains a large proportion of acceptable material, and it is usually economical to separate the good from the bad rather than to manufacture an entirely new lot."

specified limits and the chart records are accepted as proof that the product meets specifications. This particular chart also portrays the results of certain improvements achieved as the result of statistical quality control.

Information is being sent to Aluminum Co. of America from customers with increasing frequency, indicating that they are rating the quality of material received by an acceptance sampling plan. Instances are manufacturers of zippers of aluminum alloy wire, where (as every American knows) lack of dimensional accuracy means you're hopelessly stuck! Another is the manufacture of aluminum alloy rivets for countersunk holes, where flush heads are important. A head too high must be ground down; a head too low means a loose rivet. Control charts are invaluable to determine the accuracy of the heading machines; 100% inspection of the millions of products would be hopeless.

VI. Government inspection of material to be used by the armed services has utilized statis-

Fig. 4—Inspection of a Sample of Aluminum Disks

Government Sampling Tables

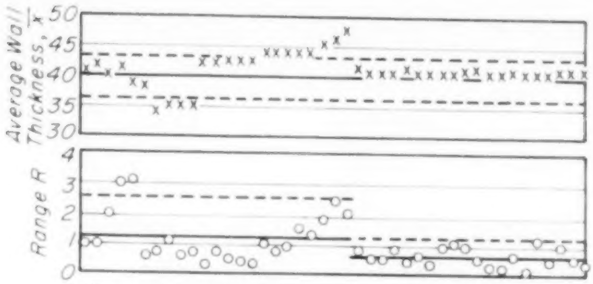
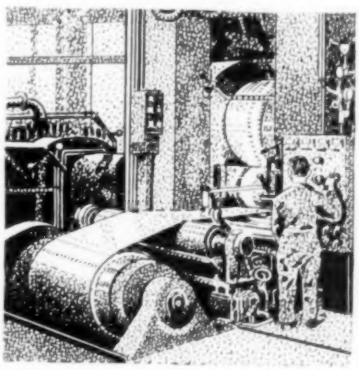


Fig. 5—Inspection of Samples of Collapsible Tubes for Wall Thickness, 1 In. From Bottom. Right half of chart records more uniform conditions after an improvement in the manufacturing process had been made

tics to a growing extent since the Army Service Forces, Office of the Chief of Ordnance, issued the first "Government Standard Inspection Procedures Based on Statistical Quality Control" in the year 1944.

A relatively new specification, known as MIL-STD. 105A, dated Sept. 11, 1950, has been issued as a "bible" to guide inspection by sampling and will, undoubtedly, play an increasingly important role in governing the rules of inspection of Government purchases.* It permits a variety of choices of standards depending upon the final use of the part or material in question. By means of tables and operating characteristic curves, the degree of risk involved in the use of any given plan can be predicted; this is valuable for both the vendor and purchaser. One feature of the tables is that they permit the frequency of inspection to be reduced as long as the quality remains above a certain level, but require more frequent inspection when the quality drops. These tables also recognize a difference in acceptability between major and minor defects in a particular product.

The principle involved here is that the Government is in fact inspecting a manufacturing process as reflected in the quality of its product. If there is mathematical assurance that the process is in control, there is no reason to spend unnecessary effort and expense in inspecting the product. This approach, as employed by the Armed Services, is one of the few items of good news to the taxpayer. As a matter of fact, this is the heart of inspecting by statistical methods.



VII. Tolerances for Machines and Methods—To explain this seventh function of statistical quality control, we will revert to the problem of maintaining the composition of aluminum alloys within the required limits. The first step in the solution of this problem is to establish the limits based on the relation of the characteristics desired to the accuracy of which the process is capable. Weighing out the components of an alloy on laboratory scales and melting them down under carefully controlled conditions in a pint-sized laboratory furnace will result in closer control of the composition than operating on a production basis in a 25-ton open-hearth furnace to which the charges are added from time to time and from which part of the metal is tapped between charges. Nevertheless, the composition must be controlled as closely as practicable in production.

How close is "practicable"? This can be determined mathematically by operating the furnace under careful supervision and taking samples at frequent intervals. By an analysis of the data, control limits are established and the process can be continued with these control limits as the guide.

Similar methods are employed to establish dimensional tolerances for thickness of sheet, angularity and straightness of extrusions, core dimensions in castings, flatness of plate, diameter of wire, head heights of countersunk rivets, and so on almost indefinitely where the variables are subject to measurement.

VIII. Control of Laboratory Methods—Each Alcoa Works is equipped with an analytical laboratory which makes all the routine analyses. Each laboratory uses approved methods and equipment. Periodically some neutral party—for example, the manager's secretary—visits the Works laboratory and selects at random a metal sample which has been analyzed. The sample is turned over to a research chemist at Aluminum Research Laboratories in New Kensington for his analysis. The two results, independently found,

*Statistical process control is also recognized in the new Military Specification MIL-Q-5923.

are then compared. Based on a great many such comparisons, standard deviations have been worked out which are used as a guide to determine the accuracy of the methods, the performance of the individual laboratories, and the evaluation of new methods and techniques.*

IX. Technical Experiments – Much valuable plant metallurgical work has been done without the aid of modern statistical methods. However, many observations and conclusions have been influenced by preconceived notions of what the results should be. Statistical analysis not only minimizes the chances for erroneous conclusions, but also enables the experimenter to plan his experiments with the minimum number of samples necessary to permit him to draw valid conclusions. This has been well expounded by Professor Burr in his article in *Metal Progress* for October 1953, and therefore needs no further elaboration here.

X. Labor Relations – The tenth and final example of the use of statistical quality control deals with the suggested use of this method in the field of labor relations. Applications to machines and methods have been discussed. Statistical quality control is also applicable to men. Without mathematical analysis it is possible to draw erroneous conclusions as to the range of quality reproducible by a man or the amount of work of which a man is capable, just as easily as it is to misjudge the characteristics of a process. Furthermore, it has been demonstrated repeatedly that men take more interest in their work if they see the results of it as portrayed by control charts. It is true that when the facts are presented on a mathematical basis, a man has more confidence in them than when he is merely told about them in general terms by his foreman. Furthermore, the foreman has more confidence in talking to his men if his story can be backed up by facts on paper.

Since graduation in 1921 from Lehigh University, John W. Hood has been with Aluminum Co. of America, and until 1944 did metallurgical work at various plants. Since that date he has been in quality standards and customers' service work in connection with all forms of aluminum and magnesium alloys. At present he is head of the quality standards department of the metallurgical division in Pittsburgh.

PRACTICAL USES

In summary, we may list a rather imposing series of practical uses of statistical quality control, as proven by experience in Aluminum Co. of America's operations. Some of them may appear a little bizarre. At any rate, they are far from the assemblage of dots on coordinate paper which rugged individualists of the old school have called "doodles" or "flyspecks". Given a friendly managerial atmosphere, many, if not all of them, can be achieved in any metallurgical plant engaged in mass production.

I. Quality Assurance
II. Operator Interest
III. Basis for Decisions
IV. Incentive to Earn Low Inspection Costs
V. Customer Quality Standards
VI. Compliance with Government Inspection Standards
VII. Establishing Tolerance – Machines and Methods
VIII. Control of Laboratory Methods
IX. Planning Technical Experiments
X. Aid in Labor Relations

No one industry has a corner on these problems of human relations and costs, and it is hoped that the examples cited from Alcoa's experience can be translated to those in other activities, in such a manner that they will be interesting and useful.

*Some queries at this point during presentation of the paper in Philadelphia brought out the fact that spectrographic analysis is in widespread use in Alcoa's control laboratories. Standard methods and standard samples have been formulated by the company's central research laboratories in New Kensington. Work along this line started about 40 years ago and is still under way. Mr. Hood observed that the use of a standard sample for spectrographic or quantometric analysis does not eliminate possibilities of errors from many sources, such as the preparation of the samples (either in casting or machining), in the sparking of the samples or adjustment of the equipment. Accuracy of routine laboratory analyses by wet methods as well is checked by the Aluminum Research Laboratories. Those interested in this phase of metallurgical control should consult two articles by H. V. Churchill and J. R. Churchill on "Evaluation of Spectrographic Analytical Data" which appeared in *Industrial and Engineering Chemistry*, Dec. 15, 1945, and Jan. 15, 1946.

Light Metallurgy

The Philosopher's Stone

THE TROUBLE WITH modern research into materials for service at high temperatures is that it is not fundamental enough. We, the metallurgists of the world, tend to tinker with this problem. We make an alloy of five or six desirable elements, selected by witchcraft or guesswork; we heat the alloy, pull it and measure the stretch. We find that less X means more stretch, or more X means less stretch. We proceed accordingly.

This, gentlemen, may be Science, but it is not Fundamental Science. We have not gone to the heart of the matter, for all our talk of lattices and precipitation hardening.

What are we after? A material we can most aptly call the "Engineer's Gold". This material must withstand a stress of 1000 psi. at 10,000° F. for 100,000 hr. with no measurable extension. It must be incorruptible and it must never, never fail in fatigue.

We are a long way from finding such a material, and the only hope of doing it is to go right back to the great fundamental physical truths, as worked out by our god-like forefathers in Science.

I am referring, of course, to the alchemists. Their major aim, during two long millennia, was to turn the common metals into gold. It is true that they never actually succeeded in doing so; but in working for 2000 years on this one problem, they must have acquired by the way certain ideas on the *method* by which they might hope to solve it. Let us, at least, try arming ourselves with the knowledge of Cagliostro and Roger Bacon, since the method of Faraday and Clerk Maxwell has failed us.

First of all, let us examine the alchemist's approach to his problem. In his view, all metals were forms of the same basic material. All were Earth, and all were informed or animated by Fire. The earth took various forms; in one form it was, say, tin, and in another form it was gold. The reason was that, in one form, seeds of tin had been implanted in the element earth, so that it had grown into tin. All that was necessary was to reduce the tin to its basic earth-state and plant gold-seeds in it, so that it would grow into gold instead. The necessary seed was what they called the Philosopher's Stone.

We can see here—if we look hard enough—a notion of the

The lists of alchemical symbols that form the background for this page, and the reconstructions on the following pages, are taken from the "Catalogue of Latin and Vernacular Alchemical Manuscripts in the United States and Canada", by Wm. J. Wilson, Osiris, Vol. 6, 1939, Bruges - Belgium.

underlying unity of matter which is not altogether distinct from our own atomic theory. At least, the belief that we can see it may give us enough moral courage to continue our search.

The alchemist was not simple enough to believe that tin, as tin, was capable of being turned into gold by the mere addition or subtraction of anything. The tin had first to be utterly destroyed, and reduced to its basic form. The entire process was a kind of destruction and resurrection, similar to that which occurs in the growing of any other crop. Corn produces seed, and dies away; the seed, destroyed by burial, produces more corn, but only if it is planted at the right season and with a certain decent ritual. It is no use putting a lot of seed into a barrel in October and expecting to find a cellar-full of corn at Christmas. Hence arose a lot of what we now regard as mumbo-jumbo in the alchemic art. If it is reasonable to expect that seed planted in autumn will rot, and seed planted in spring will grow, it is also reasonable to expect that the successful flourishing of gold-seed may only take place at certain phases of the moon, with the assistance of the drawing of pentagons, the wearing of suitable robes, and the banging of gongs.

Some metallurgist may be rash enough to interrupt me at this point to ask if I am seriously suggesting that he should melt up a lot of nickel, chromium, tungsten and vanadium in a pot and slit the throat of a yearling weasel over it by the light of the full moon, uttering at the same time certain carefully chosen passages from, say, the 1951 ⊕ *Transactions* in a high monotone.

I ask him in return: *"Has he ever tried it?"*

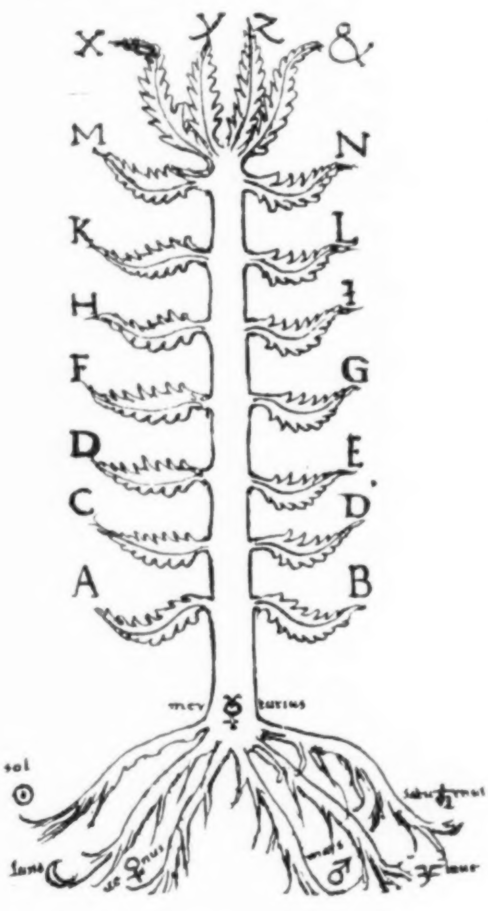
After this crushing retort, let us proceed with our inquiry. We encounter, as we look further into the works of the alchemists,two serious difficulties. One is that it is extremely difficult to understand, at any given moment, what the alchemist is talking about. His writings resemble the official statements about the atomic bomb tests in Nevada in that he is not trying to impart information; he is trying to conceal it. He has to lure the reader on by promising to disclose the secrets of the universe, but the revelation is, to say the least of it, cloudy. The alchemist was impelled, like all scientists, to publish the results of his work; but if he thought he was getting near to discovering the secret of the Philosopher's Stone, he did not want a thousand Toms, Dicks and Paracelsuses to read his recipes and get there first, ruining the market with a flood of cheap gold. On the other hand, if he thought he was a long way off and getting no nearer, he did not want to give his failure away. In either case what he did was to wrap his ideas in a lot of the most unutterable clotted nonsense that can be found in any section of the world's literature.

The other difficulty is that when the alchemist talks about tin he is quite often not talking about what the world commonly regards as tin. He is talking about Sophic Tin, a kind of pure, tin-minded tin, the abstract ideal toward which all tin is aiming, although it never reaches it.

This confusion led a lot of alchemists astray.

It was common knowledge in those days that all metals were composed of sulphur and mercury in varying proportions. The metallurgist may protest that I said previously that all metals

Fig. 1 – The "Tree of Metals" With Sol, Luna, Venus, Mars, Jove and Saturnus as the Roots, Mercurius as the Trunk, and Opposite Pairs of Leaves A through M, Culminating in a Top Cluster Marked X, Y, Z, &. (Courtesy of Osler Medical Library)



were earth informed by fire. So I did. The statements are quite consistent. The earthy or mineral part of the metal is symbolized by mercury, and the fiery or combustible spirit of metals is represented by sulphur.

The ordinary common-or-garden alchemists, the hard-working bellows-blowing fellows who were universally referred to in the Middle Ages, with friendly sarcasm, as "puffers", wasted a lot of time trying to synthesize gold from common mercury and sulphur. They used to boil up these materials together in a crucible (or Philosopher's Egg), or distill them from an alembic and condense the vapors, weaving pentagrams over them and what not. It did no good. All they ever got was a deplorable stink. If they had acquired financial backers they often put some real gold in, and they knew enough about cupelling to get it back; but they never got out any more than they put in.

The real, genuine alchemist knew better. He knew that his starting point for the synthesis (the Great Work, as it was called) must be mercury and sophic sulphur. Often he spent the whole of his days toiling to obtain these materials without ever starting on the real Great Work at all. The wisest alchemists of all were more fundamental still; they never so much as touched a bellows from one phase of the moon to the next, but spent their lives poring over old manuscripts, trying to find out how the trick had been worked by the ancient Egyptians, who notoriously knew all about it. Unfortunately, the Egyptians had wrapped up their knowledge in the usual alchemic verbiage about Set and Nephthys, Sol and Luna, or the marriage of the Faire Whyte Woman to the Ruddy Man.

Besides the controlled growth of goldseed and the synthesis from the sopic pseudomorphs of sulphur and mercury, these wise old alchemists opened up other avenues which might well be explored by the latter-day metallurgist in his search for the Engineer's Gold. There is, for example, the conception of tingeing:

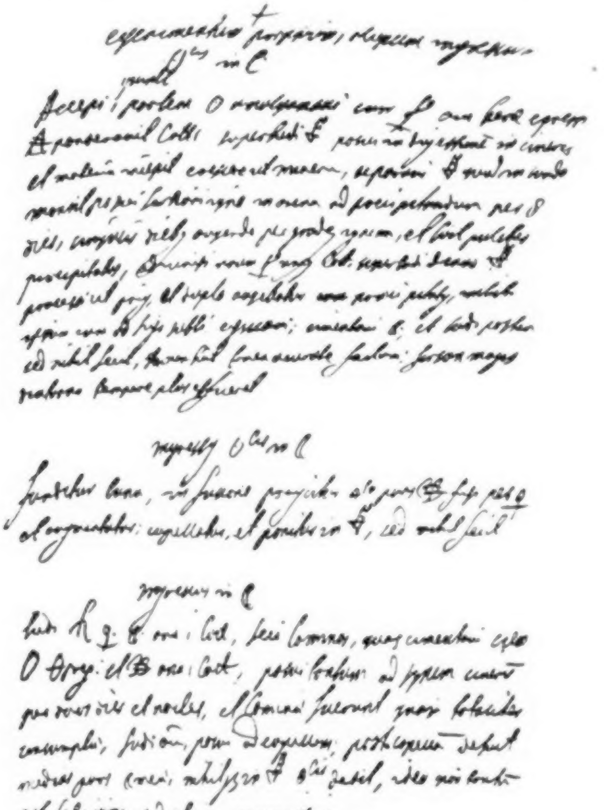
The alchemists, analyzing the essential differences between gold and the common metals, observed that most of the latter were gray and, so to speak, combustible; while gold was yellow, and incombustible. The yellowness, as they saw it, might be a product of the incombustibility; or the incombustibility might be a product of the yellowness. If you could only tinge zinc, or lead (or washing-soda for that matter) to the precise color of gold, it might well turn out actually to be gold!

There is a lot of work to be done still on this tingeing business. We are faced at once with the difficulty that we do not know precisely what may be the tinge of the engineer's ideal creep and fatigue resistant material; but such difficulties exist only to be surmounted. If there is no other way of finding out, there is bound to be, somewhere, an ancient Egyptian or pre-War German manuscript which will tell us.

I hope I have said enough to inspire a few metallurgists with the idea of tapping the wisdom of the alchemists of the past. There is only one thing that makes me nervous, and that is that the engineers might cotton onto the business and declare that the high-temperature material they require, in addition to possessing all its other unimaginable virtues, must also be sophic.

R. P. Lister

Fig. 2—This Alchemical Recipe not Only Produced no Gold but Destroyed Half the Silver Put Into It "ideo non tantum est falsissimus, sed etiam rapacissimus". (Courtesy of Harvard College Library)



Atomic Energy in Postwar Britain

*BY H. W. B. SKINNER**

As everyone knows, we exploded our first trial bomb at Montebello in September of 1952. Since some of Britain's best scientists worked with American scientists on the bomb-design project, you may think that this was slow going, but it must be remembered that during the war most of our atomic energy organization had been merged with yours, or engaged in building up Chalk River in Canada. At the beginning of 1946, therefore, it was necessary to build up from scratch, without the advantage of full cooperation. Since the U.S.A. was building up the stockpile of bombs as rapidly as possible, there was no overriding incentive from a strategic point of view for us to get on quickly with a much smaller one of our own.

Contrary to the expectations of most of the senior scientists who had worked in the wartime project, the Atomic Energy Organization was placed firmly within the Civil Service. I thought at the time that this was a serious mistake, and my opinion has not changed with the passing of years.

Although the salaries of the bottom and middle grades have now become satisfactory, the top-grade salaries in the establishments, especially engineering, are still far less than in corresponding industrial posts. More fundamentally, there is the fact that Civil Service scientific establishments always seem to run into stagnation.

Very few details about the Atomic Energy Establishments have been given to the public other than to list their functions:

Harwell, Berks., for research into nuclear physics and atomic energy, and the provision of basic scientific data.

Amersham, Bucks., a subsidiary of Harwell concerned with chemical preparation of natural radioactive substances and radioactive isotopes.

Risley, Lancs., for the design and operation of plants for producing fissile material.

Springfields, Lancs., for the preparation of pure uranium from ore concentrates.

Windscale, Cumb., for the production of plutonium in atomic piles.

Capenhurst, Ches., for the separation of U^{235} by diffusion.

Aldermaston, Berks., for research work on atomic weapons.

These establishments were officially stated to be engaged on "atomic research, development, and production for military and civil purposes". From 1946 to the end of 1951 the cost has been roughly $280,000,000.

It has been officially stated that in this country we do not propose to go ahead with propulsion engines until experience has been gained on stationary plants. However, on account of the wasteful and increasing use of ordinary fuels during this century, there seems little doubt that during the next century the world will be in desperate need of new fuel.

The coal fields of Britain have been estimated to have an economic life of 200 to 300 years, at the current rate of use. But real costs are already rising in spite of increased mechanization of the pits. There is no possibility that power from waterfalls, wind, and tides can take over any appreciable fraction of the load. Although there is an enormous untapped source of energy in sunlight, this is probably going to be difficult to use without turning over vast acreages of otherwise wanted agricultural land to fuel production.

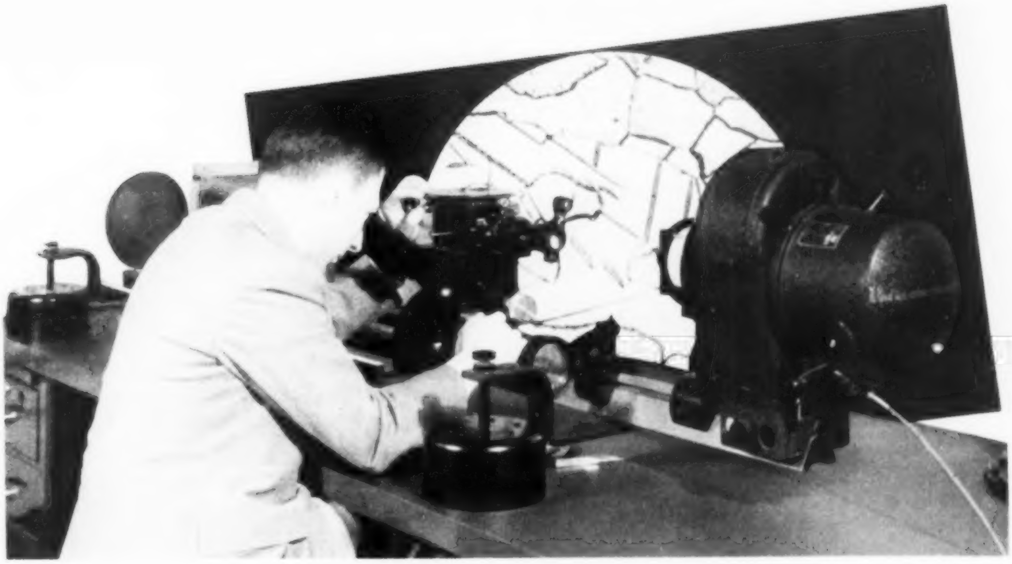
Therefore, in spite of all the known disadvantages of uranium as a fuel, the world in the course of the next century or so may *have* to turn to it as one of its main fuels, if not the most important.

Of course, we are well aware of the difficulties involved in the effective use of the U^{238} isotope and of the large capital charges for plant, as well as the cost of difficult and expensive chemical recycling processes on the material. But such details may be almost irrelevant, if we decide the world will have to make use of uranium to supplement coal, rather than trying to assess whether it can compete with it economically on present-day terms.

Further, in view of the very large capital expenditure which would have to be undertaken to make any significant contribution to total world production of electric power, and of the time-scale suggested for the exhaustion of present fuel reserves, the sooner we get on with the job the better off we will be.

It has been stated officially that an experimental atomic power station will be built on a site adjacent to the Windscale plant, as part of a double program designed to test the possibilities of natural uranium piles and of breeder reactors. I personally would like to see a long-term program for Britain put in hand to add, by the end of a 20-year period, *at least* 10% to our national installed electric generating capacity of 16,000,000 kw. Such a program would be quite feasible. The current rate of expansion of our ordinary generating capacity is quite considerable, and a large capital expenditure is in any case being put into the industry. The cost per kilowatt of installed capacity in atomic power stations is likely to be high, but, even so, the expense of a program such as I have outlined should not be excessive. It would give a long-range objective and a considerable degree of stability to our atomic energy project, besides adding a modest contribution to the total resources of the country and preparing the way for the future.

*Dr. Skinner was deputy director at Britain's Harwell Atomic Energy Establishment from 1946 to 1950. The quotations are from a copyrighted article in *Bulletin of the Atomic Scientists*, June 1953.



Metallographic Structures in Commercial Titanium

By ROMAN OSADCHUK, WILLIAM P. KOSTER and JOHN F. KAHLES*

PURE TITANIUM can exist in two different forms: (*a*) body-centered cubic beta above 885° C. (1625° F.), and (*b*) hexagonal close-packed alpha below this temperature. By the addition of alloying elements, the high-temperature beta phase can be partially or completely retained at room temperature and the phase equilibria at elevated temperatures may also be controlled. If an alloy is heated to an elevated temperature and then cooled in various ways, the phase transformation which takes place during cooling may produce microstructures that will differ widely in appearance at room temperature.

One basic factor controlling microstructures of titanium is the phase relationship at the solution heat treating, forging or rolling temperature. Whether all-alpha, all-beta, or a mixture of alpha and beta is present depends on this temperature and the alloy content. Generally, such alloys contain alpha stabilizers, beta stabilizers, and both alpha and beta stabilizers, respectively. Alpha stabilizers include aluminum, carbon, oxygen, and nitrogen. Beta stabilizers include elements such as chromium, iron, vanadium, molybdenum and manganese.

If all-alpha is present, there is no transformation during cooling and the microstructure will consist of equiaxed grains of alpha. If all-beta is initially present, several things may occur. Alloys containing large amounts of beta stabilizers will undergo no transformation and all of the beta will be present as equiaxed grains at room temperature; those containing moderate amounts of beta-stabilizing elements will gradually undergo substantial, but not always complete, transformation to alpha. (In some instances it is possible to retain this otherwise

*Mr. Osadchuk is research fellow in metallurgical engineering at University of Cincinnati. Dr. Koster is assistant director of metallurgical research of Metcut Research Associates, and Dr. Kahles is partner of the same organization.

unstable beta at room temperature by a very rapid quench.) Structures range from grain-boundary alpha and coarse, lamellar alpha produced at slow cooling rates to fine, acicular alpha at very fast cooling rates. Alloys containing little or no beta stabilizer usually will transform rapidly and completely to alpha structure on cooling.

Frequently, these beta-to-alpha reactions are of the nucleation type, but a martensitic (shear) transformation can be produced in some alloys. If alpha and beta are coexistent at the solution treating temperature, the alpha will be unaffected and appear after cooling as equiaxed grains. The beta will undergo transformation in one of the ways just described, depending upon the cooling rate and alloy content. It is apparent from the foregoing that many complex structures may be expected in these alloy systems.

Although there is some variation in hardness and strength accompanying the changes in microstructure, generally this change is not very great. The behavior of titanium alloys in this regard has been disappointing. However, certain titanium alloys can be successfully quenched and aged.

During forging and solution heat treating, considerable amounts of oxygen and nitrogen may be absorbed at the surface of the titanium alloys. The introduction of these alpha-stabilizing elements causes the formation of large grains of alpha at the surface. This alpha is equiaxed in RC-130 B while somewhat needle-like in Ti-150 A, the external conditions being the same in each case. This condition is illustrated in Fig. 1 and 2. This manifestation of atmosphere absorption indicates a comparatively slight depth of penetration. However, observation of low-temperature transformations carried out isothermally, which happen to be very sensitive to oxygen and nitrogen concentrations, indicates a gas-sensitized layer up to 0.030 in. thick in MST 2.5Fe-2.5V following a soaking for 60 min. at 900° C. (1650° F.) in an electric muffle furnace. The difficulty of analyzing titanium for oxygen

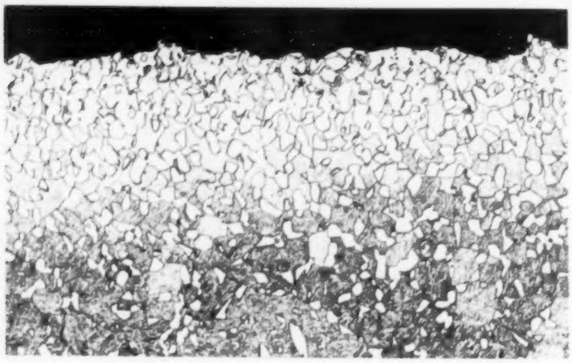


Fig. 1 (Above) – RC-130 B, Heated 4 Hr. at 1800° F., Water Quenched. Shows equiaxed alpha grains stabilized at the surface due to atmospheric contamination. 100×

Fig. 2 (Below) – Ti-150 A, Heated 4 Hr. at 1800° F., Water Quenched. Shows needle-like alpha grains stabilized at the surface due to atmospheric contamination. 100×

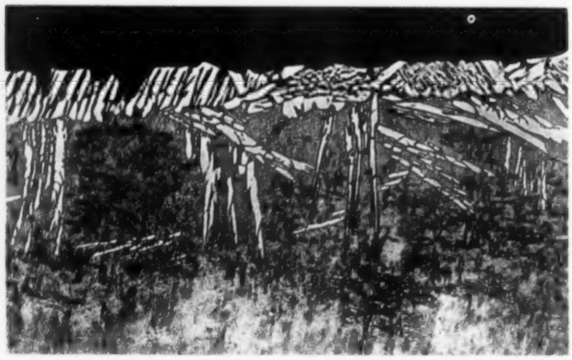
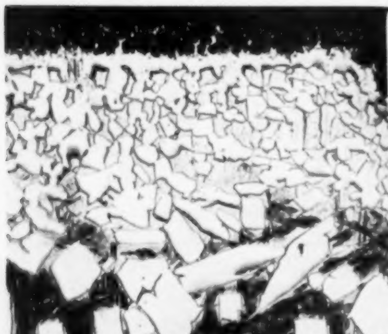


Fig. 3 – RC-130 B, Pack Carburized in Charcoal 15 Hr. at 1800° F., Showing Carbides (Black) and Alpha (White Particles). 100×

Fig. 4 – Ti-150 A, Same Treatment as Fig. 3. Note the much deeper carbide layer formed in this alloy. 100×



has prevented further work in this regard.

Pack carburizing of several titanium alloys was also carried out for 15 hr. at 1800° F. The case, easily visible with the unaided eye, consisted of an outer hard but very brittle layer of carbide, and an inner layer of alpha, the latter being caused by the alpha-stabilizing effect of carbon and the atmosphere. This is shown in Fig. 3 and 4.

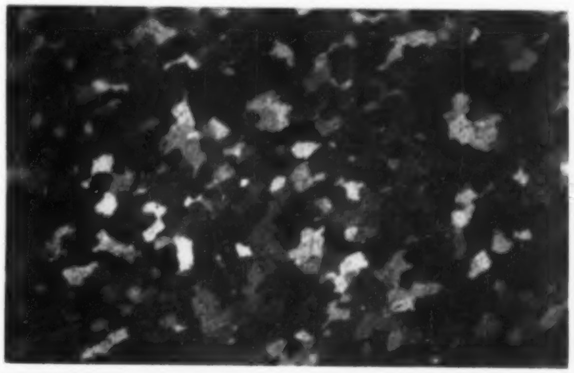
PHASE IDENTIFICATION

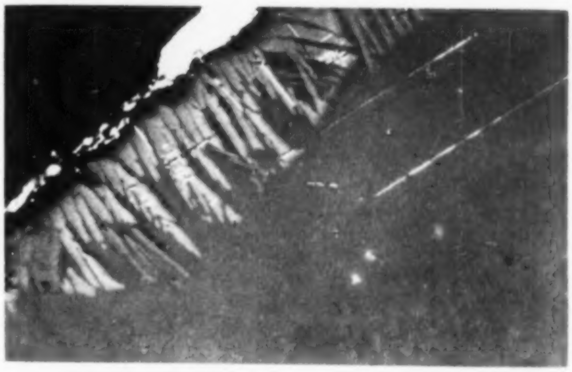
The identification of the several phases appearing in titanium alloys may, at first glance, seem highly difficult. In addition to equiaxed alpha, beta, and beta decomposition products, insoluble phases of titanium such as carbide, hydride and telluride may be present. Therefore, a general knowledge of the alloy systems involved greatly simplifies this problem of phase identification. As in all metallurgical work, accurate information regarding the alloy content of a material and the heat treatments to which it has been previously subjected is highly desirable.

X-ray analysis is particularly helpful in substantiating the predictions and observations of metallographic structures. All-alpha and all-beta alloys can, of course, be identified, but their identity usually can be assumed from the chemical composition. Where alpha and beta co-exist, X-ray analysis can be very helpful in revealing the total amounts of each phase. This can be done most conveniently with a Geiger-counter spectrometer to record the X-ray diffraction pattern. In many alloys this determination can also be made by direct optical inspection of the structure, although optical methods generally indicate less beta than is actually present. This statement is made on the assumption that X-ray analysis presents a more accurate evaluation of the existing structure than does optical observation.

Polarized light used on a polished but unetched specimen is very effective in revealing alpha if it is coarse and equiaxed. Under such

conditions, alpha will alternate between red and slate blue as the polarizing stage is rotated; the beta will remain dark and unchanged. In order to use polarized light successfully, the surface of the sample must be free of scratches and disturbed metal. Magnifications under 500× are preferable. Specimens which have been etched may be examined in this way, but the contrast obtained between alpha and beta is not nearly as marked as in the unetched condition. Fine basketweave structures can be examined, necessarily at magnifications above 500×. While an indication as to the phases





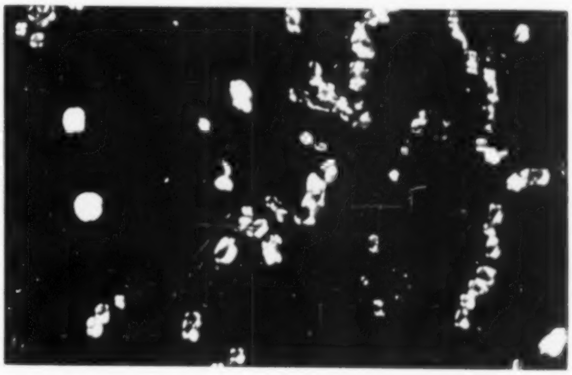
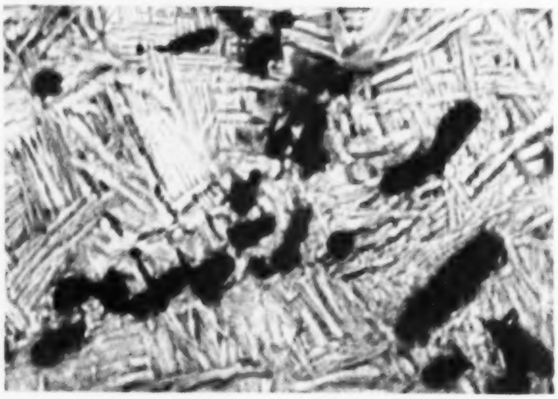


Fig. 5 (Top)—Annealed (As-Received) Ti-100 A. Grain delineation of equiaxed alpha is brought out by means of polarized light. Unetched, 100×

Fig. 6—Ti-150 A, Heated 4 Hr. at 1800° F., Water Quenched. Elongated alpha grains caused by surface contamination. Polarized light, unetched, 100×

Fig. 7 (Bottom)—MST 5 Fe-5 V Heated 1 Hr. at 1800° F., Water Quenched. Carbides are white and equiaxed beta grains (outlined faintly) are black. Polarized light, etched, 500×



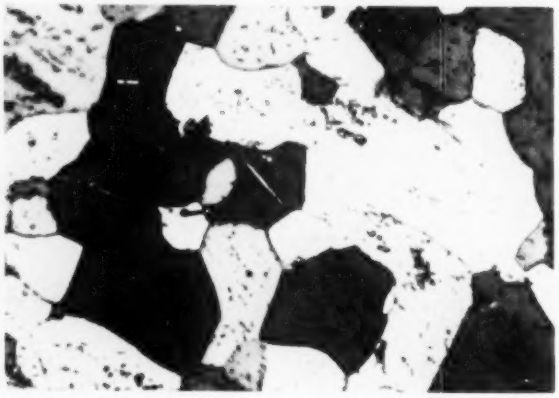


Fig. 8 (Top) – RC-130 B Heated 1 Hr. at 1750° F., Water-Quenched. Heat tinted to show equiaxed alpha (white) and acicular alpha or transformed beta (dark). 500×

Fig. 9 (Center) – As-Forged MST 2.5 Fe-2.5 V. Heat tinted to show carbides (black) and basketweave alpha. 1500×

Fig. 10 (Bottom) – Annealed Ti-75 A. Heat tinted to outline equiaxed alpha grains and give good contrast. 500×

present in such structures can be gained, it is believed that polarized light will not produce totally reliable results. Typical structures for which polarized light was found helpful are shown in Fig. 5, 6, and 7.

HEAT TINTING FOR PHASE IDENTIFICATION

Heat tinting has indicated some promise of being helpful in phase identification work. Polished specimens, before and after etching, were heated in air at 500° F. until a light golden-pink film appeared. The surface to be treated was cleaned with ether just prior to the tinting operation, so that uniform oxidation could take place. Carbides in material treated in this way first become bright blue and then darken with longer tinting times. Alpha remains white for some time and then gradually darkens, though not nearly as fast as the carbides. Hence alpha and carbides can be easily distinguished. Transformed beta structures darken quite readily during heat tinting. Furthermore, it is possible to secure grain contrast and much better grain boundary outline in an all-alpha alloy by tinting than could be obtained by even the heaviest etching. The results of some of these techniques are shown in Fig. 8, 9, and 10.

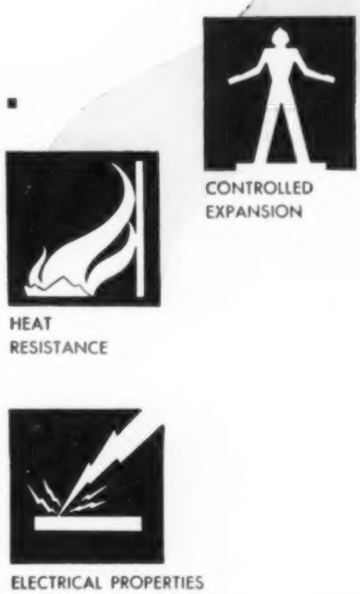
Some distinction can be made between alpha and beta with ordinary etching. Alpha will etch darker than beta in hydrofluoric etchants, providing the material is etched rather heavily. It becomes difficult, however, to identify beta when present in a fine basketweave or acicular structure of alpha.

ELECTROLYTIC ETCHING

Electrolytic etching has proved satisfactory for the differentiation between certain phases present in titanium alloys. P. R. Mallory and Co. suggests electrolytic etching with a 10% sodium cyanide solution* swabbed on the surface of the specimen which is polarized anodically. Time and voltage requirements vary widely depending upon the material being etched. A properly treated specimen will appear violet or blue. The carbides will be bright yellow-orange; alpha will be a lighter blue than beta, if both alpha and beta are present. In general, electrolytic etching is a suitable method for phase identification because of the convenient application of staining and because the possibility of structural changes, as might occur in heat tinting, is eliminated. Further work with this technique would seem warranted.

*Such a solution is used to darken carbides in steel. See "Metals Handbook", 1948 edition, p. 397.

What problems face you...



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Work-Hardening Characteristics combined with thorough graphite distribution make NI-RESIST ideal for metal-to-metal wear service.

Ni-Resist of normal hardness machines like 200 BHN gray iron and is readily weldable.

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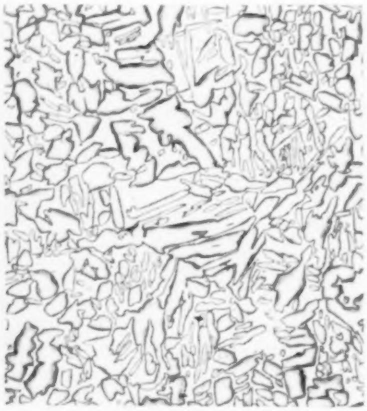
Typical Microstructures of Commercial Titanium Alloys

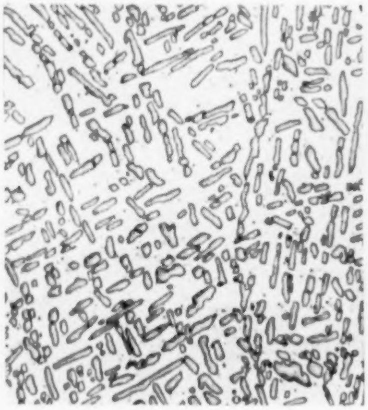
Micros courtesy of Roman Osadchuk, Research Fellow in Metallurgical Engineering, University of Cincinnati, and William P. Koster and John F. Kahles, Assistant Director of Metallurgical Research and Partner, Respectively, Metcut Research Associates. Hand polished except as noted.

RC-130 B, As-Received. Electropolished, 500×

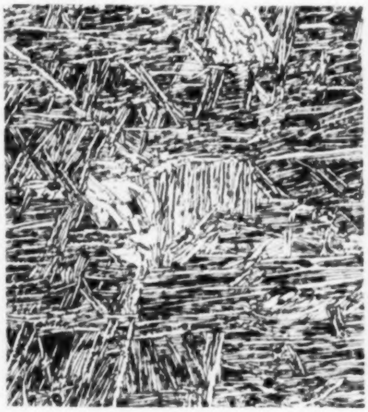
RC-130 B, 150×. Quenched in Water From 1400° F.



RC-130 B, 150×. Quenched in Water From 1500° F.



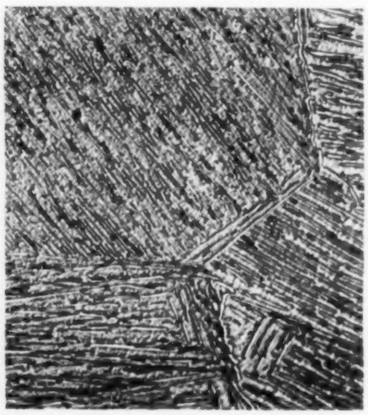
RC-130 B, 150×. Quenched in Water From 1600° F.



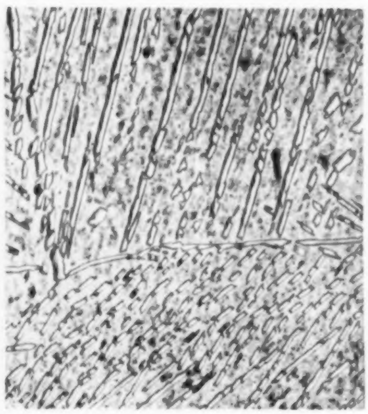
RC-130 B. Air Cooled From 1800° F, 150×

MST 3 Al – 5 Cr. As-Received, 250×

Ti-150 A. As-Received, 500×



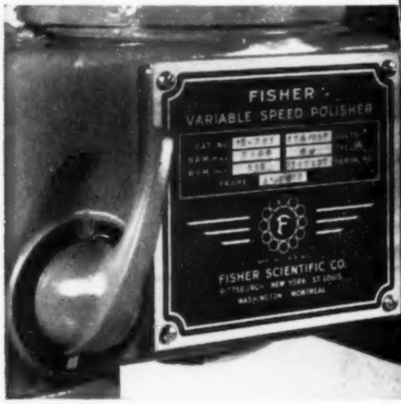
Ti-150 A, 150×. Quenched in Water From 1450° F.



Ti-150 A, 150×. Quenched in Water From 1525° F.

Wide Control, Constant Torque *with* FISHER METALLOGRAPHIC POLISHER

The motor frame and polishing bowl casting are attached to a steel bracket; the unit can be easily mounted to a laboratory wall.



A selector dial (within easy reach of the operator) permits wide range of speeds without loss of torque.

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All exposed parts of the Polisher are constructed of non-corrosive materials. The bowl and splash ring are made of aluminum for durability. The bowl is sloped towards a drain plug, readily accessible from the underside of the unit. The splash ring is removable and is shaped to direct the spray from the head down into the bowl.

The nickel-silver polishing head has a 9-inch diameter. A unique locking-clutch device connects the head directly to the driving shaft, facilitating removal and attachment.

A stainless steel spring firmly holds polishing cloths of any thickness and a satin-finished nickel-plated brass cover protects the head and polishing cloth from dust when Polisher is not in use.

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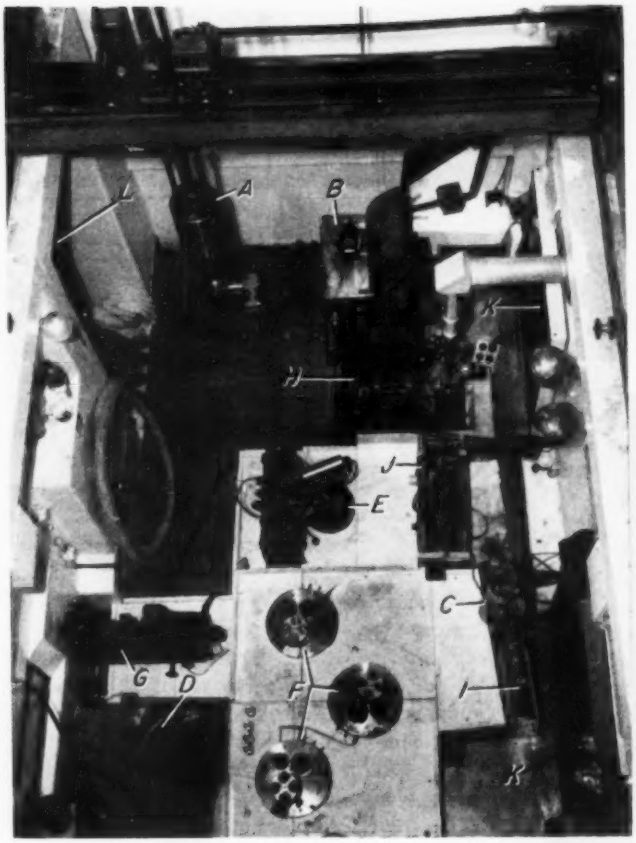


Fig. 1 – Cell Housing the "Hot" Metallographic Laboratory, as Viewed From Above

A – Electric manipulator
B – Cut-off machine
C – Mounting press
D – Lapping machine
E – Specimen cleaner
F – Polishing machines
G – Metallograph
H – Hardness tester
I – Diamond dispenser
J – Etching device
K – Windows
L – Steel door

Metallography of Highly Radioactive Materials

THE STUDY of the effects of irradiation on metals is an important phase of the work on nuclear reactors. When materials have been exposed to neutron irradiation, the metallographer is confronted with the problem of preparing and examining highly radioactive samples. Such work requires a remotely operated "hot" metallographic laboratory; it must provide shielding for protection of personnel, as well as facilities to confine air contamination and radioactive wastes.

The remote metallographic section of the solid state division began operation in November 1952. The general techniques used in sample preparation do not differ greatly from standard laboratory procedures, despite the complete loss of individual control in exercising the skills of metallography.

All of the metallographic equipment is housed in an area roughly 6x10 ft. The area is enclosed by 3 ft. of heavy aggregate concrete on all sides. Two 32x38-in. windows, 36 in. thick, and a 6-in. thick steel door provide

by M. J. FELDMAN
Solid State Division
Oak Ridge National Laboratory
Oak Ridge, Tenn.*

*Valuable assistance has been rendered by Albert F. Zulliger of the engineering department of Oak Ridge National Laboratory and Robert J. Gray of the metallurgy division, who worked on the original design of the polishing machines; by Stewart Dismuke of the solid state division for help in cut-off wheel design and Brice Kinyon of the engineering department who designed the specimen cleaner.

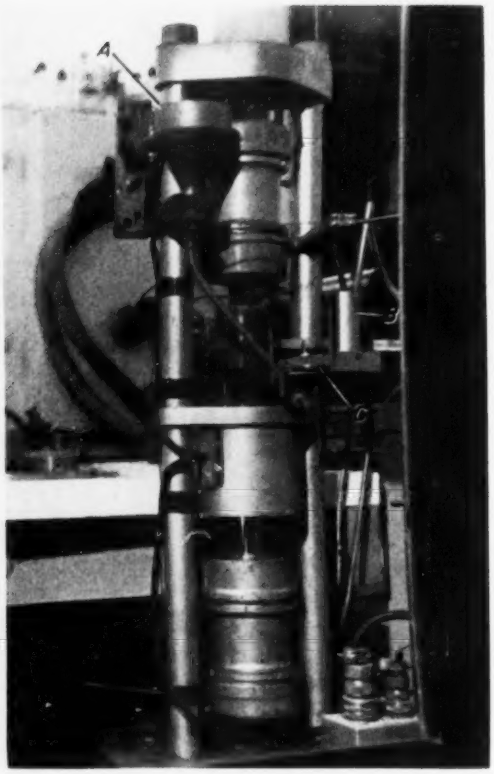


Fig. 2 — Remote Mounting Press
A — Revolving funnel
B — Standpipe for washers
C — Transfer arm

means for servicing and viewing the operation. A rectilinear electric manipulator provides the "hand" necessary for transferring from one step to another. An overhead view of the cell is shown in Fig. 1.

The samples are sectioned for examination on the remote cut-off wheel shown at B in Fig. 1. This operation has three purposes: (*a*) The area of greatest interest is exposed for examination; (*b*) the amount of radioactive material to be handled is reduced to a minimum; and (*c*) the surface imparted to the sample by the wet cutting wheel does not require any belt or disk sanding to prepare it for the initial polishing operation. All operating parts of the machine are enclosed so as to control contamination and also to facilitate recovery processes. Cutting speed is controllable, a sump provides for water-cooled cutting, and variable vise pressures can handle a range of sample types. Samples larger than $1\frac{1}{2}$x15 in. cannot be handled on the cut-off wheel and are sectioned in an adjoining cell that houses a "remote machine shop".

When a metallographic sample has been cut it is transferred to the remote mounting press shown in Fig. 2 (C of Fig. 1), placed on the lower mounting cylinder, and lowered into the heating chamber. A predetermined amount of bakelite powder is added to the mounting chamber by the manipulator through the revolving funnel (A in Fig. 2). The preweighed bakelite powder controls the height of the mount to 0.750 in. $\pm$ 0.1 in. This tolerance is necessary for uniform sample height in subsequent operations. A 15/16-in. identification washer of soft steel is also permanently mounted on the upper face of the mount. The washers are stamped with an identifying number and stacked in the standpipe (B in Fig. 2). They are remotely attached to the magnetized face of the upper piston by a transfer arm (C). Because of the critical dimension restrictions placed on the diameter of the bakelite mounts ($\pm$0.001 in.), they are cooled 25° C. under pressure.

Green bakelite powder was found to provide the most stable dimensions of the various mounting powders available.

The mounted samples are then placed in a 12-in. "Crane Lapmaster" (D in Fig. 1) for rough polishing. This commercial lapping machine required a minimum of physical alteration to render it usable in the cell. The samples are held in individual weights by a permanent magnet which attaches itself to the soft steel identifying disk. 800-mesh alumina is fed automatically to the lapping plate by the machine. Usual lapping time is 20 to 30 min. On samples that have been sectioned elsewhere and are therefore not as smooth as those produced on the cut-off wheel the lapping time may become very long. For very rough samples that cannot be resurfaced on the cut-off wheel, the milling machine in the remote machine shop can be equipped to surface-grind mounted specimens. A magnetic chuck is used to hold the bakelite mount. (Here, as throughout the process, the soft steel identifying disk serves as a means for gripping the mount magnetically.)

When the samples have been lapped sufficiently they are transferred individually to the specimen cleaner (E in Fig. 1). The cleaner is one of the most critical steps in the polishing procedure and is unique even in remote work. While cleanliness of sample is always stressed in a metallographic laboratory, no special precautions other than clean hands and a clean source of solvent are necessary. In remote handling the problem becomes much more

complex. While the apparatus shown in Fig. 3 appears mechanically complex, it is really a compact collection of simple mechanisms. The loading clamps (A in Fig. 3) hold the sample while the manipulator removes the magnetic holder used in the lapping stage. These clamps then move the sample past a rotating brush (B) and over to the rotating magnetic grip (C), release, and move back to their original positions. With the grip rotating at 200 rpm., two sprays of solvent (D) cleanse the sides and surface of the specimen. Then a high-velocity jet (E) of "Eng-Sol" solution traverses the sample face while the magnetic grip increases its rotational speed to 1800 rpm. On the return traverse of the high-velocity jet, the solution flow is stopped and a jet of heated, filtered air dries the sample. When the jet has returned to its original position, the unloading clamps (F) move in, grip the sample and remove it for manipulation to the next stage. The cleaning cycle is so controlled from the panel that any of the three major steps can be stopped at will or repeated if necessary. Each sample passes through the cleaning cycle four separate times during the complete preparation process.

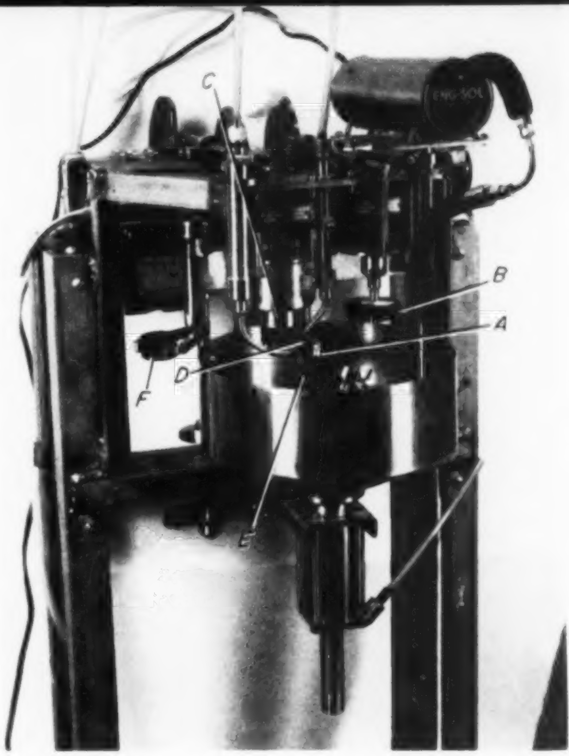


Fig. 3 – Special Specimen Cleaning Equipment

A – Loading clamps *D – Cleaning sprays*
B – Circular brush *E – High-velocity jet*
C – Rotating magnetic grip *F – Unloading clamps*

After the lapping compound is cleaned off the sample enters the standard polishing stages. Three standard Buehler low-speed polishing wheels (F in Fig. 1) have been modified for this purpose. The three polishing stages are distinguished by the particle size of the diamond polishing medium used. The first stage uses 6 to 12-micron diamond on a cloth wheel, the second 1 to 6-micron on a lead lap, and the third 0 to 1-micron diamond on a cloth.

A modified polishing wheel is shown in Fig. 4. The cover plate (A) houses solvent tubes (B) used in flushing the wheels, a window (C) and the bearing for the specimen turret (D). The turret (E) is revolved in a direction counter to the rotation of the polishing wheel by means of a gear at E′.

Specimen holders (F) have a permanent magnet at their lower end to hold the sample (G), and are hollow so they can abe weighted with lead; their caps (H) are so designed that a permanent arm placed on the cover plate

Fig. 4 – Polishing Wheel Modified for Mechanical Manipulation

A – Cover plate
B – Solvent tubes
C – Window
D – Bearing for turret
E – Specimen turret
E′ – Gear for specimen turret
F – Specimen holders
G – Sample
H – Cap for specimen holder

"Hot" Metallography at Oak Ridge

will impart a quarter turn to the sample per revolution of the turret. The sample rests freely on the polishing cloth and is held square to the cloth by virtue of a clearance of 0.001 in. between the hole and the specimen holder assembly. Lubricant suitable for diamond polishing is added through a controllable drip-type lubricator.

Diamond compound is added directly to the specimen face of the bakelite mount before it is inserted in the turret. The diamond dispenser shown in Fig. 5 and at I in Fig. 1 has removable caps (A) which swing back so the manipulator can hold the sample just above the dispensing tips. Air pressure forces a plunger in against the diamond paste and extrudes a short stream of paste onto the specimen surface. Under usual circumstances one addition of diamond paste to a wheel is sufficient to last for one or two days of operation.

Polishing times vary in the different stages according to the material being polished. The second stage is a lead lap used extensively to maintain a flat surface to the edges on corrosion specimens. It may be bypassed in processing samples where some rounding of the edge can be tolerated.

When the sample has been cleaned after final polishing it is placed on the metallograph shown in Fig. 6 and 7. This is a standard Bausch & Lomb "GBILS" metallograph built into a lead wall. A 6-in. extender tube was placed between the ocular and the shutter, and the wall constructed around this tube. The metallograph is suspended on standard shock absorbers and enough clearance allowed between the wall and the metallograph (and its controls) to prevent vibrations from reaching the instrument. In addition to the fine focusing control, the coarse focusing and stage controls were brought out of the cell mechanically (A in Fig. 7). Figure 6 inside the cell shows a tungsten arc source that has recently been replaced by a 300-watt zircon arc source. In Fig. 7 the ground glass viewing screen is shown outside the cell. At the right of the metallograph is a window made up of four 2-in. sheets of high-density glass. This window provides a convenient viewing port for manipulating samples to the Lapmaster and the metallograph.

If the sample appears to be properly polished it is transferred from the metallograph to the etching manipulator shown in Fig. 8 (J in Fig. 1). Simple vertical and horizontal motions are provided by the train (A). The sample is picked up from the positioning track (B) by a permanent magnet (C), immersed in etching solution (D), washed in a fountain of water (E), dipped in alcohol (F) and finally dried by a heated air stream (G).

Etching is the stage of remote preparation that provides the greatest difficulties. This is na-

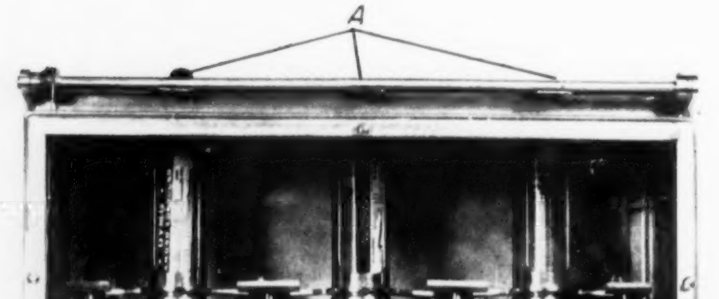


Fig. 5 – Diamond Dispenser. Removable caps shown at A

tural since it is in etching procedures[3] that the metallographer must exercise considerable skill. Many standard etching procedures do not lend themselves to remote work. Often the time necessary to manipulate the sample from the etchant to the wash fountain is longer than the usual time of etching. In some instances the concentration of the etchant can be changed successfully, but many times a change in concentration means an undesirable change in etching characteristics.

Staining also presents a rather complex problem. Consistent production of stain-free specimens is difficult when the sample is generally not viewed from the time of its final polish until it has been etched and dried. However, stains are not an insurmountable difficulty. In the first place, they do not always mask the information we are seeking, and if they do, steps can be taken to overcome them. Because of the long time consumed in preparing metallographic samples by remote control and because there is always available a large backlog of work to be done, the criterion for determining whether a sample is acceptably prepared must be based on the information desired from that sample. Our product is often comparable to that of a "cold" metallographic laboratory. In all of our work, processing is repeated until the experimental questions can be answered. A few scratches or slight stains that in no way detract from the validity of the photographable information are often tolerated.

At the present time we are using a batch process; a batch consists of the samples contained in four bakelite mounts. Actual working time from cutting to photography is two days. Total time, including preparation, transfer time, decontamination and clean up, is about one week.

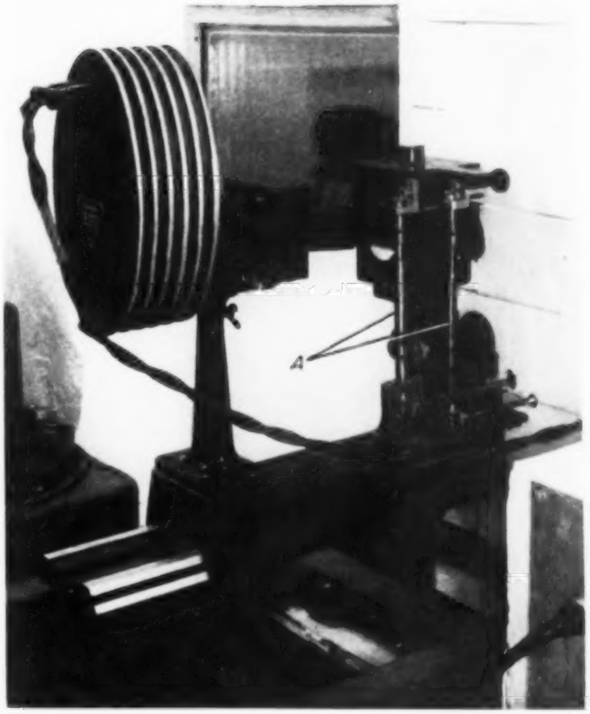


Fig. 6 – Portion of Metallograph Inside the Cell Showing Tungsten Arc Source

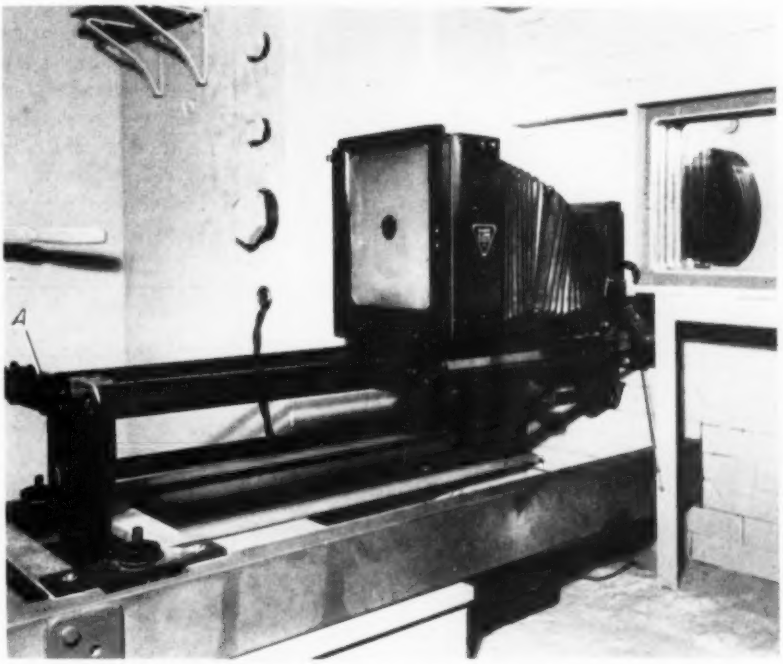


Fig. 7 – Outside the Cell Are the Ground Glass Viewing Screen of the Metallograph, and the Fine Focusing, Coarse Focusing and Stage Controls at A. The observer is protected by a wall of lead bricks. Window is four 2-in. sheets of high-density glass

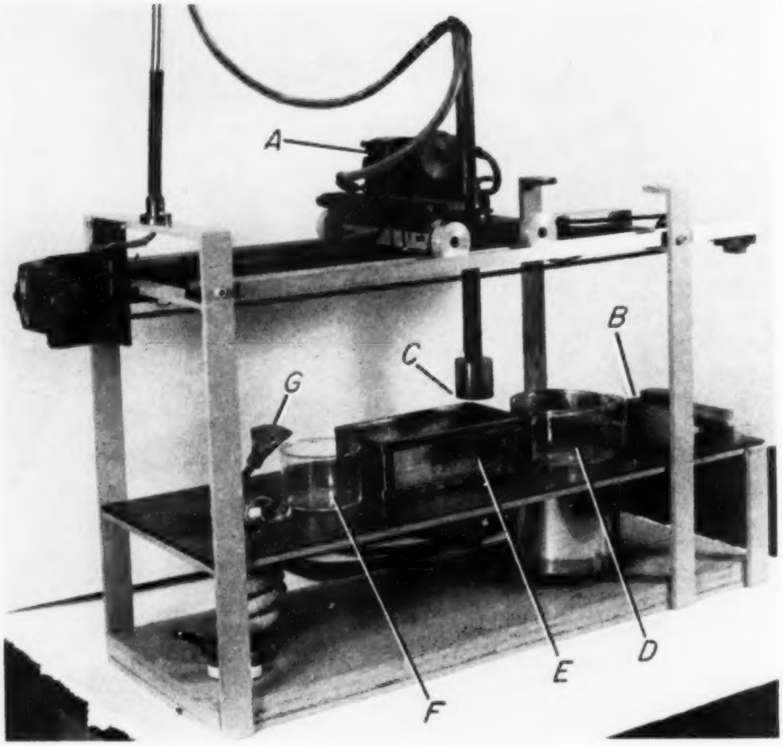


Fig. 8 – Etching Manipulator
A – Train device for moving specimen
B – Positioning track
C – Permanent magnet
D – Etching solution
E – Fountain of water
F – Alcohol bath
G – Air stream

The remote mechanical polishing equipment that has been developed will handle a wide range of materials. We have developed procedures for preparing samples of mild and high-carbon steel, Types 310, 316, and 347 stainless, copper, 2S and 24S-1 aluminum, molybdenum, tungsten, brass and Inconel. Figures 9 and 10 show some typical micrographs which represent the capabilities of the system. (Because of the "classified" or secret nature of our work at Oak Ridge, very few of the photomicrographs we have taken with this equipment can be published.)

While the installation and satisfactory operation of more-or-less conventional mechanical polishing equipment was considered to be our first problem, we have not passed up the obvious advantages in many situations of electrolytic polishing and etching. Equipment for this purpose is being developed – now that the original problem seems to be solved – and will be in operation in the near future.

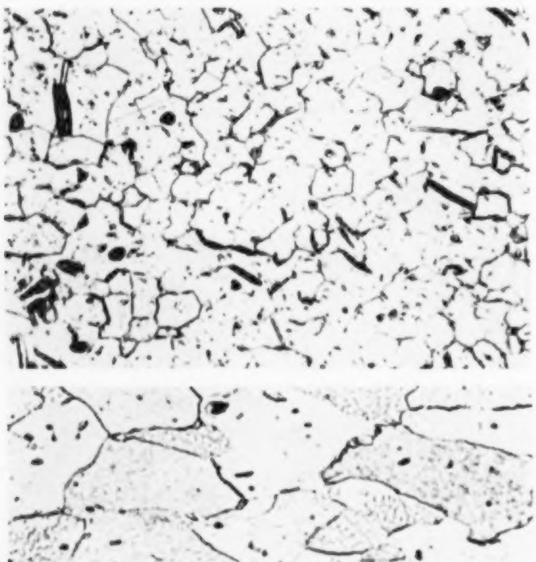
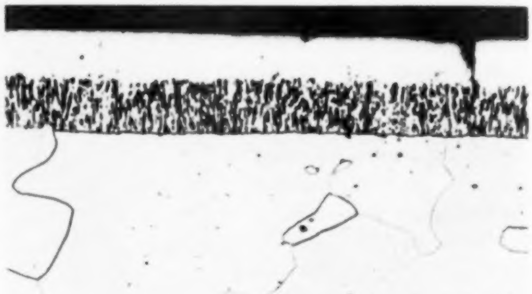


Fig. 9 – Specimens of Titanium (Top) and Tungsten (Bottom) Photographed by Remote Control. 250×

Fig. 10 (Below) – Specimen of Molybdenum Having a Surface Layer of $MoSi_2$, Indicating That Little or no Rounding of Edges Occurs in This Equipment



Short Runs

Heat Treating

HEAT TREATING FURNACES used in steel mills come big, and one of the giants among them will be the one Drever Co. will install in the Coatesville, Pa. plant of Lukens Steel Co. for treating stainless steel plate. It will handle plates up to 2 in. thick, 130 in. wide and 20 ft. long. Over-all length of the line will be about 365 ft., being made up of a 50-ft. charge table, 202-ft. roller hearth furnace, 10-ft. transfer table, 42-ft. long 1000-ton quench press and a 50-ft. discharge table arranged to swing 90° for crane pick-up of the plates.

Temperature range will be 950 to 1950° F. Heat treating cycles will be variable from 10 min. to 12 hr. to accommodate the wide variety of stainless and other steel analyses for which the equipment is intended. Rated capacity is 13,250 tons per month for annealing of stainless steel. The furnace will be direct fired with combination natural gas or oil luminous flame burners. Temperature control will be proportioning and divided into 10 zones 20 ft. long. All conveyer rolls, furnace doors and swing mechanism for the discharge table will be controlled from a single station located adjacent to the quench press.

Finishing

A UNIQUE corrosion resistant coating which is claimed to impart the protective advantages of stainless steel to common ferrous compositions has been invented by Gerald J. Horvitz, technical director, New York Testing Laboratories, Inc.*

The new process employs phosphorus which, when alloyed with metallic constituents in fairly large percentages of the total composition, greatly reduces the melting point and increases the fluidity of the alloy combination. Thus, the melting point of nickel is brought from 2640° F. to about 1600° F., allowing application at moderate temperatures with good alloying and bonding to the base metal.

Basic materials for this process are nickel oxide and various phosphorus compounds which are applied much like a paint to the surface of the base metal to be treated. These materials are easily available and are of relatively low cost.

The mechanism of producing the alloy is one of reduction under heat whereby metallic nickel and phosphorus are produced. In this reduction, advantage is taken of the fact that ammonium acid phosphate salts decompose in a reducing atmosphere at elevated temperatures to form phosphine, water vapor, free ammonia, hydrogen and nitrogen. Reducing gases, along with liberated hydrogen, produce a metallized form of nickel from the oxides. Simultaneously, phosphine reacts with nickel oxide and nickel to form metallic nickel phosphide. Since rather small amounts of phosphorus alloyed with nickel greatly reduce the melting point of the combinations, there results a wettable and flowable coating at the temperature of the operation. The usual reducing temperature range is

(Continued on next page)

*Patent No. 2,633,631, issued April 7, 1953.

Welding

One of the country's largest aluminum foundries is now using Heliarc welding to correct imperfect castings. The castings, some of which are for vital defense production, must pass rigid quality inspections. The foundry uses a special line for this reclamation work which is done quickly and economically, yet produces X-ray quality welds.

Usually the only preparation required is grinding, although preheating is used if the area to be welded is particularly large. After the necessary preparation, the welding is done with a Heliarc torch using special rods cast by the foundry. Every weld is X-rayed before the casting is released for assembly. (Photo courtesy Linde Air Products Co.)

1550 to 1700° F. This is in the range of usual normalizing for steels and therefore will not cause excessive grain growth.

Where vessels are too large to be treated by a regular furnace operation, an alternate method comprises spraying of the nickel-phosphorus alloy directly to the surface to be treated. Advantage is then taken of the flowability and wetting properties of the alloy combination to produce proper bonding to the base metal. Induction heating or other suitable localized reduction heating methods can be used in the application.

Joining

THE METHOD of squeezing together two pieces of metal to form a strong joint, a technique being used for a number of applications in England where it originated, is now available in this country. In this process, called pressure or cold welding, ductile metals are joined by forcing together faying surfaces under a pressure great enough to cause considerable displacement of metal. The bond (shown in Fig. 1) resulting from the intermolecular flow of metal is reported to have a tensile strength greater than that of the parent wire.

A hand tool, made by Utica Drop Forge & Tool Corp. for Koldweld Corp. (the licensee in this country for this process), is shown in Fig. 2. The wire ends are placed in the holes of the dies on top of the tool, brought into correct position by adjusting the knob on the right, and the handles are then squeezed to make the weld. In addition to its use for the butt welding of wire, the Koldweld process, as it is called, can be used to join flat strips of nonferrous metals, using another special tool.

Fig. 1–Wire Section Showing Pressure Welded Area After Tensile Test

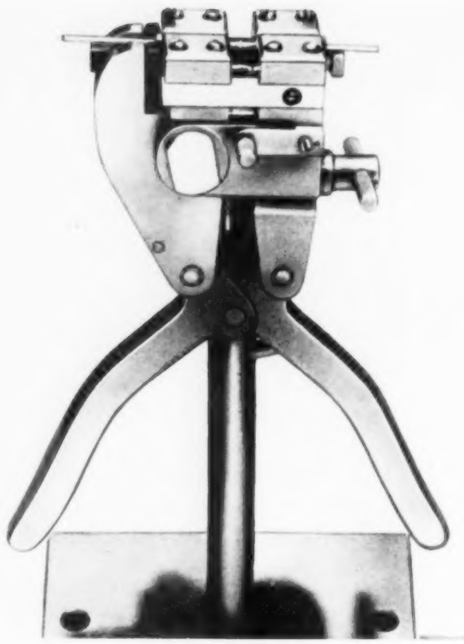


Fig. 2–Hand Tool for Butt Welding Wires by the Pressure Method

Grinding

Thousands of Dollars in Diamonds Are Saved With Cloth Sack Tied to Pipe Bleeding off Coolant and Sludge From Grinder at the Carboloy Dept. of General Electric Co., Detroit

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. - In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

High-Chromium, High-Carbon Iron

. . . the Iron That Hardens as it Wears

In many applications involving extreme abrasion, ordinary work-hardening alloys are not suitable. This is because most of these alloys require a definite pounding action for a martensite transformation, and the scouring action of an abrasive is not sufficient for development of high wear resistance. For this reason, high-chromium, high-carbon irons were developed – irons that wear-harden.

Chromium Content of Irons Ranges from 24 to 30 Per Cent

These irons are made in the electric furnace and have the following composition range:

Chromium	26 to 28 per cent
Carbon	2.60 to 2.80 per cent
Manganese	0.50 to 1:25 per cent
Silicon	0.25 to 0.75 per cent
Sulphur	max. 0.05 per cent
Phosphorus	max. 0.05 per cent
Nickel	minimum
Iron	balance

Irons of this composition are readily castable by steel casting techniques.

Development of Greater Wear Resistance by Heat Treatment

Structurally, these irons consist of primary iron-chromium carbides in a matrix of iron-chromium solid solution and secondary iron-chromium carbides. They are hard in the as-cast condition (500 to 550 Brinell), but when they are given an austenitization heat-treatment they develop much higher hardness (about 600 Brinell), and also have greatly improved wear resistance. Austenitization consists of heating these irons to a temperature of about 2012 deg. F. for an hour, then allowing them to cool in air. This heat-treatment promotes the formation of very unstable austenite—austenite that will transform to a harder martensitic end-product even under rubbing or mild impingement action. Austenitization has been found to be far more effective in increasing wear resistance than the promotion of unstable austenite by the addition of ferrite-forming alloying elements.

High-chromium, high-carbon irons can also be annealed to sufficiently low-hardness values for grinding or simple machining. Hardnesses as low as 350 to 450 Brinell can be obtained by heating the castings to temperatures of 1400 to 1450 deg. F. for 12 to 24 hours, then allowing them to cool in air.

Irons Have Wear Resistance Many Times That of Other Alloys

Austenitized high-chromium irons have been known to last as much as 21 times longer than other wear-resistant alloys in applications involving extreme frictional abrasion. These applications include sand-blast nozzles and liners, pantograph contact shoes, grinding disks, pulleys, chute-liner plates, dredge-pump liners, and rollers for crushing various hard materials.

In a recent test, high-chromium iron was compared to special wear resistant steel castings as the material for hammers in a machine that was used to crush abrasive material. The chrome-iron hammers were found to have almost 7 times the wear resistance of the steel castings.

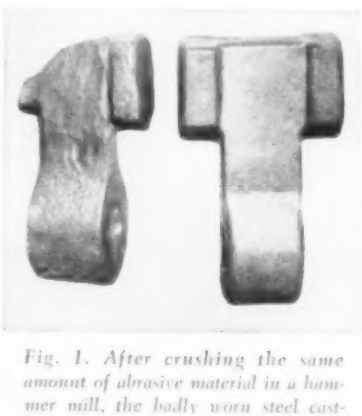


Fig. 1. After crushing the same amount of abrasive material in a hammer mill, the badly worn steel casting (left) had a weight loss of 37 per cent while the high-chromium iron casting (right) lost only 5.5 per cent.

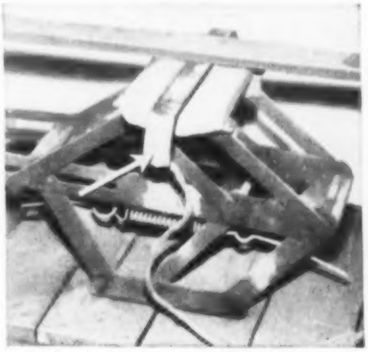


Fig. 2. This chrome-iron pantograph shoe had a service life of about 10 years. A tool steel that was used in similar service wore out in about 3 or 4 months; copper lasted about 24 hours.

When thoroughly backed up with zinc, the iron also has enough shock resistance to be used effectively as crushing hammers and jaw plates for many severe rock-handling jobs.

Metallurgical Service Available

For years, ELECTROMET high-carbon ferrochrome has been used to make chromium additions to abrasion-resistant high-chromium irons. If you should have any questions about either the production or use of these irons, write to the nearest ELECTROMET office. Our metallurgists will be glad to give many valuable suggestions and recommendations on how to make or use this iron most effectively.

Write for a free copy of the ELECTROMET publication, "Abrasion Resistant High Chromium Iron." This booklet is a collection of some of the best available information on how to make and to use abrasion-resistant iron castings most efficiently.

Correspondence

Gas Mixtures for Carbo-Nitriding

ROCKFORD, ILL.

We are very much interested in the article "Structures and Properties of Some Carbo-Nitrided Cases" in the June 1953 issue of *Metal Progress*. This article presented data on carbo-nitriding which was very much needed. However, we would like to make a few comments on the gas flows used, since these differ considerably from our carbo-nitriding practice.

The dual aim of carbo-nitriding is *(a)* to build up the carbon on the surface of the steel and *(b)* introduce enough nitrogen into its case to increase the hardenability so that sufficient hardness is obtained by a mild quench. The carbon is supplied to the steel by a carrier gas together with an enrichment gas (such as natural or propane) and the nitrogen is supplied by ammonia. Our gas flows and the flows used by Mr. Valentine (for oil quench only) are compared below.

CONSTITUENT GASES	IPSENLAB MAX.	IPSENLAB MIN.	VALENTINE
Carrier	89.5%	96.5%	76.5%
Natural	3	3.2	5.6*
Ammonia	7.5	0.3	17.9

*Equivalent to approximately 11% natural gas.

This difference in practice is further accentuated by the fact that the ratio of natural gas to propane, when a change is made from one to the other, is 2 to 1. We have found that an excess of ammonia or enrichment gas will cause a poor microstructure of the case, resulting in free carbides and excessive retained austenite. It is even possible to form complex iron-nitrogen-carbon compounds with an excess of ammonia. It is our belief that the seemingly better results for the cyanided test bars and the dark etching constituents in the carbo-nitrided test bars might be due to the large amount of ammonia and propane used.

The types of cases that can be produced by carbo-nitriding are many and varied due to the availability of an additional element (nitrogen), and its effect apparently is nearly as great as that of the carbon content in carbonizing.

FRANK HOBBS
General Manager
Ipsenlab of Rockford, Inc.

Patents Under the Atomic Energy Act

MADIERA BEACH, FLA.

The review of the A. S. T. M. Symposium on Radio-isotopes in the September Issue of *Metal Progress* fails to make clear the distinction between ordinary patents and patents coming under the 1946 Atomic Energy Act classification. Section 11b "Patents and Inventions" of the Atomic Energy Act takes precedence and supersedes other actions or laws, thereby allowing use of such patents on the research and development level. This is very important to industry for two reasons. First, this is contrary to normal patent rights, and second, most of the present radio-isotope uses are exploratory and would come under the newer interpretation of Section 11b. Consultation with patent attorneys is recommended if use of patented radio-isotope processes is contemplated.

DON M. MCCUTCHEON
Consultant in Engineering-Physics

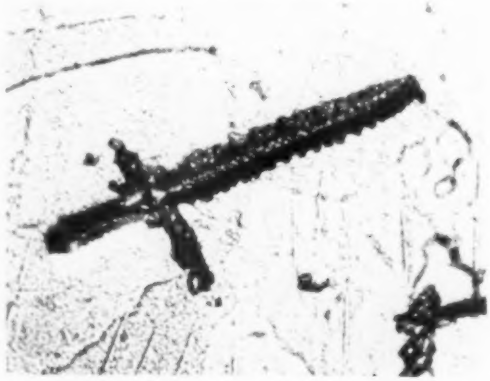
Sword of Science?

AMES, IOWA

The micrograph seems to have disclosed Will Burnett's "double-edged sword of science". Appropriately, it was found in a piece uranium.

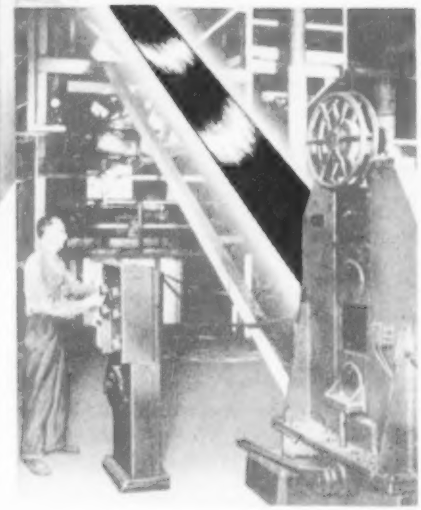
This oxide inclusion appeared in a sample of alpha uranium, etched cathodically.

E. J. MANTHOS
Metallographer
HOWARD L. LIVINGSTON
Metallurgist
Ames Laboratory
Iowa State College



(More Correspondence on p. 108)

¼ MILE of PSC ANNEALING DUCT in Steel Plant of INLAND



Continuous strip steel annealing system at the Inland Steel Company plant, designed and built by Inland and Selas Corp. of America. PSC annealing ducts in black at top.

PSC 'Light-Weight' Alloy Equipment Solving Many Engineering Problems

This installation of PSC alloy duct for continuous annealing of strip steel is another example of how PSC "thin wall" construction is helping solve present-day engineering problems. Installed in the Indiana Harbor plant of Inland Steel Company, the system represents advanced designing in heat treating methods.

PSC "thin wall" construction effects hitherto impossible compactness and removability. It also introduces large economies in many types of construction, due to the savings in metal and to the lower fabricating and installation costs. Specializing in the precision fabrication of the weight-saving sheet alloys, PSC furnishes coils, ducts, flumes, manifolds, muffles and tubing for every heat and corrosion-resistant requirement; also tubes for radiant furnaces, and for furnace externals such as vent stacks. In any size and alloy.

Send for Heat Treating Catalog 52

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Adapting the B & L Balphot for Eberbach Tests

INDIANAPOLIS

The Eberbach microhardness tester cannot be used directly on the Bausch & Lomb Balphot metallograph because its height is greater than that of the objective. However, the microscope can be adapted for the Eberbach tester, and those who have this equipment may be interested in knowing that this adaptation was made by the following alterations:

1. Mounting the microhardness indenter in a standard Balphot objective handle.

2. Making a new stage plate which raises the specimens approximately 0.200 in. The exact clearance was obtained by trial and error, this clearance being the exact distance required for the application of indenter load by lowering the stage with the cam-elevating mechanism.

3. Modifying a standard objective adapter to elevate the objective lens by approximately 0.200 in. to compensate for the raised stage plate. This provides focusing of the impression by lowering the stage with the cam-elevating mechanism.

This adaptation permits rapid examination of the impression simply by removing the indenter and inserting the objective lens. Figure 1 shows the new stage plate and microhardness tester in place on the metallograph; Fig. 2 shows the objective adapter in place of the microhardness tester.

A filar micrometer eyepiece is used to measure the diagonals of the impressions produced. Recalibration of the eyepiece is necessary because of the increased height of the objective. A dial indicator is used to measure the distance between impressions, particularly where a complete traverse across a specimen is made.

Drawings of the modified stage plates and the objective adapter which we made probably would not be suitable for others since adjustment of the exact dimensions of the stage plates and objective adapter will depend on the exact over-all length of the particular Eberbach microhardness indenter involved.

DOROTHY B. HOLBROOK
Laboratory Assistant
C. O. Sundberg
Research Metallurgist
Diamond Chain Co., Inc.

Overheating Temperatures of Boron Steels

BETHLEHEM, PA.

In addition to the errors arising from your changing "heats" to "ingots" in the tabulated data and in Fig. 2 ("Effect of Boron on the Overheating Temperature of Steel," *Metal Progress* for August 1953), I note another rather serious error on page 83. I refer to your caption on the top of the page stating "Boron Steels Overheat Easily". The casual reader would be led to believe from this caption that all boron steels are prone to overheat at a low forging temperature, whereas it is clearly pointed out in the text and conclusions that the lowering of the overheating temperature occurs only with the boron steels made with the addition of 12% boron alloy.

Since boron steels have proved invaluable during the critical shortage of strategic alloys, it is regrettable that this misleading statement appears in the article. It is the author's thought that a correction should appear in one of the forthcoming issues of your magazine.

JOSEPH FIELD
Metallurgical Supervisor
Bethlehem Steel Co.

Fig. 1 – Balphot Metallograph Equipped With New Stage Plate and Microhardness Tester

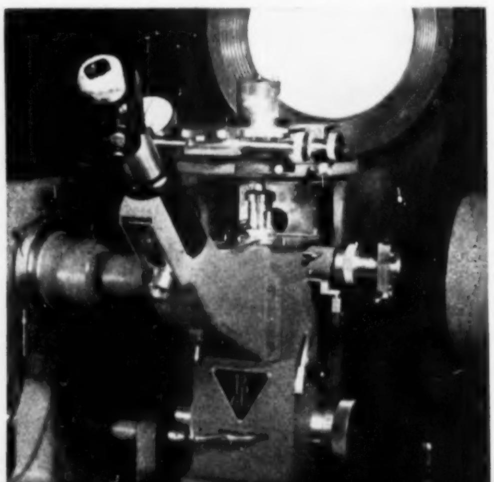
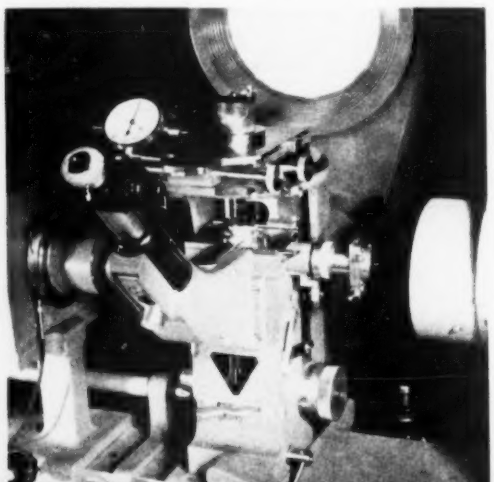


Fig. 2 – New Stage Plate and Objective Adapter in Place on the Metallograph



Personal Mention

Bruce Chalmers

Harry A. Schwartz

BRUCE CHALMERS ⊕, who for the past five years has been professor of physical metallurgy at the University of Toronto, Canada, is now on the staff of Harvard University, Cambridge, Mass., as Gordon McKay professor of metallurgy. In addition to his duties there, Dr. Chalmers continues to act as editor of *Acta Metallurgica* (reviewed in the July 1953 issue of *Metal Progress*) and *Progress in Metal Physics*. Dr. Chalmers is a graduate of the University of London, England, in physics and later received his Ph.D. and D.Sc. also at London University. From 1932 to 1938 he was a lecturer in physics and mathematics at the same university, and from 1938 to 1940, he was on the staff at the Tin Research Institute as physicist. A term as senior experimental officer in the Ministry of Supply in London followed, and he later served as head of the metallurgy division of the Royal Aircraft Establishment in Farnborough, England. From 1946 to 1948, Dr. Chalmers held the position as head of the metallurgy division of the Atomic Energy Research Establishment at Harwell, going from there to the University of Toronto. Dr. Chalmers is the author of several books and numerous papers on physical metallurgy, and is a member of the Institute of Metals and the Iron and Steel Institute.

HARRY A. SCHWARTZ ⊕, for many years manager of research for National Malleable and Steel Castings Co., Cleveland, and a leading malleable iron metallurgist, has recently retired from full-time work. His services will be available to the company, however, in a newly created position of assistant to the vice-president in charge of production. Dr. Schwartz has been associated with National Malleable since 1902, and in 1912 established for the firm the first complete research department in the foundry industry. He is the author of "American Malleable Cast Iron" and "Foundry Science", and has often been honored for his contributions to the iron field, both in this country and in Europe. Dr. Schwartz holds honorary degrees from Case School of Applied Science (now Case Institute of Technology) and from Rose Polytechnic Institute, where he graduated in 1901. For his many technical and scientific contributions to the foundry industry, Dr. Schwartz was awarded the John A. Penton Gold Medal of the American Foundrymen's Association in 1930, and in 1939 received the E. J. Fox Gold Medal of the Institute of British Foundrymen, being the only American ever to receive that honor. He was named by the Malleable Founders Society for his outstanding contribution toward progress and development in the malleable iron industry, and in 1951 was awarded the Charles H. McCrea Medal by his company.

Roy S. Kerns ⊕ has retired from the Oxweld Railroad Service Division, Union Carbide and Carbon Corp., Chicago, as metallurgist and design engineer and moved to Phoenix, Ariz.

Richard Summers ⊕ has resigned his position as metallurgist in charge of radiography at Bridgeport-Lycoming Division of Avco Mfg. Corp., Stratford, Conn., to devote full time to the management of the newly organized Quality Control Co., Bridgeport, Conn. Mr. Summers holds the office of treasurer and technical director of the company.

J. B. Froblom ⊕ has been appointed sales engineer for the James H. Knapp Co., Los Angeles.

John J. Stobie, Jr. ⊕, formerly sales engineer in the Chicago home plant of Apex Smelting Co., has been transferred to the company's new Los Angeles plant in a similar capacity.

J. Joseph Smith ⊕, manager of the locomotive division plant of the American Locomotive Co., Schenectady, since 1945, has been named manager of plant facilities for the company.

William J. Thomas ⊕ has been appointed general manager of the tubular products division of the Babcock & Wilcox Co., Beaver Falls, Pa.

James H. Moore ⊕, formerly director of metallurgical research for National Research Corp., Cambridge, Mass., has been appointed general manager of Vacuum Metals Corp., a subsidiary of National Research Corp.

R. R. Hershey ⊕ has been transferred from the Milwaukee office of the Timken Roller Bearing Co. to the Detroit office of the company.

D. Gardner Foulke ⊕ has been appointed manager of electrochemical development of Hanson-Van Winkle-Munning Co., Matawan, N.J., and will be in charge of the laboratory phase of research and development work. Dr. Gardner was formerly chief chemist for the company.

Fig. 1. Photomicrograph of sheet with large irregular grains. Printing quality not up to par.

Fig. 2. Changes in plating conditions produced crystals more columnar in shape. A step in the right direction.

Fig. 3. Here is the structure that was found to give consistently good results. The copper deposit is of intermediate hardness and contains long, thin columnar crystals.

research at work!

A LABORATORY CAN SHORTEN THE SEARCH FOR A BETTER PROCESS

Copper, a basic and important requisite for the printing of Sunday magazines for metropolitan newspapers, has—since the introduction of rotogravure printing process in the United States—suffered from cylinder wear marks which have kept the industry puzzled, and often resulted in defective printing to such an extent that blemishes in printing were easily discernible to the eye—and although not too disfiguring, there remained the necessity for their elimination for the purpose of perfecting the gravure printing operation. In collaboration with a publisher, owner of one of the most modern plants in the world, Revere Copper and Brass solved this perplexing problem and is continuing to contribute to the technical improvement of the rotogravure printing process.

In preparing cylinders for printing roto sections, copper is plated on them before engraving. The electroplating of copper is rather an old process, and its techniques are well understood. By varying current density and composition of the solution, many different types of copper deposit can be obtained. But which of the various methods would give the best results in this case? Rather than engage in a lengthy process of trial and error, the publisher, who felt that the crystal structure of the deposited copper held the key, asked us if we would collaborate.

What Were the Crystals Like?

Sheets of copper resulting from different plating techniques were sent to Research, which not only made photomicrographs of the grain structure, but also determined tensile strength and hardness. As was expected, there were large variations. Some specimens had large and irregular crystals; in others, they were long and thin, like fibers standing on end. In tensile strength, the range was from about 31,000 to 56,000 p.s.i. Diamond Pyramid hardness numbers ran from 62.9 to 141.5.

Over a period of time five different sets of samples were submitted to the laboratory, which made detailed reports on each. By correlating these with his own records, the publisher was able to evaluate the effects of changes in plating techniques. The field of his investigation became narrower after each laboratory report, and in the end it was possible for him to obtain medium-hard, fine grain deposits which require little grinding and polishing. These results now are duplicated daily on a commercial basis. Today the publisher is noted for the exceptionally fine printing quality of his rotogravure sections. The newspaper is The Inquirer, Philadelphia, Pa.

If You Do Not Have a Laboratory

This is an outstanding example of the value of applied research. Many companies occasionally need information that can only be supplied by a laboratory, but are not justified in spending the large sums required to buy and maintain scientific equipment, and to employ qualified research personnel. These firms naturally seek outside sources of the data they require. Revere was glad to cooperate in this instance, because it produces large quantities of copper anodes for plating, and has both the equipment and the experience to make thorough tests of electro-deposited copper sheets or layers.

* * *

The Revere Research Department operates a laboratory that contains the latest scientific equipment, including the spectrograph and X-ray diffraction apparatus. If you feel the need of laboratory work on copper and its alloys, or aluminum alloys, please get in touch with the nearest Revere Sales Office.

REVERE

COPPER AND BRASS INCORPORATED

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Mills: Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.—Sales Offices in Principal Cities, Distributors Everywhere.

SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

William E. Mahin has been appointed technical director of Vanadium Corp. of America and will direct the technical and research activities of the corporation. Mr. Mahin was formerly director of research for the Armour Research Foundation, Chicago.

J. H. Hartwell, formerly product engineer for the Reed Roller Bit Co., Houston, Tex., is now vice-president and plant manager for the newly formed Diamond Industrial Tool Co., Shreveport, La.

R. G. Nordstrom has resigned as manager of market development of the Torsion Balance Co., Clifton, N.J., to join the Ingersoll Products Division of the Borg Warner Corp., Chicago, as assistant to the president, and is in charge of new product research.

E. R. Freeman is now employed by Continental Can Co., Coffeyville, Kans., as supervisor and metallurgist of the quality control laboratory.

Andrew J. Griest, Jr., who was formerly employed at Battelle Memorial Institute, Columbus, Ohio, as research metallurgist, is now in the metallurgy department at Lehigh University as project leader on fine powder permanent magnet research while completing work for a Ph.D.

H. J. Holquist has been appointed assistant manager of the cold finished bar division of Joseph T. Ryerson & Son, Inc., and will continue to make his headquarters in Chicago where he has been connected with the division in a sales capacity.

Jay DeEulis, formerly technical editor of the news bureau at the Carboloy Department of General Electric Co., Detroit, has been named manager of the bureau. Mr. DeEulis, who was at one time engineering editor of *Steel*, joined the Carboloy News Bureau in November 1952 shortly after his release from the Navy.

Eugene J. Schwetz has been recently transferred from the Chicago Works of National Malleable & Steel Castings Co. to its new subsidiary, the Capitol Foundry Co., Phoenix, Ariz., as chief metallurgist. Mr. Schwetz's former position was that of project metallurgist.

Continuous Casting of Nonferrous Metals*

THERE are two different methods of continuous casting – one whereby liquid metal is fed between cooled rolls (as suggested by Bessemer), and the other whereby liquid metal is poured into a cooled cylinder and a solid rod is withdrawn from the bottom. It is the principle of this latter method that forms the basis of the author's work.

An interesting suggestion is made to the effect that the continuous casting of titanium seems likely to be feasible along the lines presently developed for steel. Continuous casting may have two advantages, the one being an increased output over present methods and the other improved and more uniform quality.

The author built a machine which, while not a duplicate of present-day commercial continuous casting plants, does, in his opinion, provide all the necessary facilities for his investigation. The 7-ft. high machine is capable of producing ingots of 1 in. diameter and at least 3 ft. in length.

Three kinds of melting units were employed: For lead, zinc and tin and the low melting point alloys, this was a carbon crucible heated by a ring gas burner. Aluminum was melted in an electric resistance furnace, the sillimanite pot being wound with "Kanthal" tape 0.125 x 0.01 in. in cross section and having a resistance of 0.579 ohm per ft. The carbon crucible used with this furnace was coated externally with alumina to reduce oxidation. Copper and cast iron were melted in a high-frequency furnace from which the molten metal was transferred for casting to an injector furnace provided with oxygen-enriched firing. The approach of the author to the question of the size for the control orifice (0.1 in.) is typical of the general treatment of the whole investigation, namely the mathematical method.

The intent of the author in his

(Continued on p. 116)

★Digest of "Aspects of the Continuous Casting of Nonferrous Metals", by B. H. C. Waters, *Metal Treatment and Drop Forging*, Vol. 19, September 1952, p. 379-384; October 1952, p. 433-438; November 1952, p. 474-478, 482; December 1952, p. 526-530, 532; Vol. 20, January 1953, p. 3-10, 20-22; February 1953, p. 79-83; March 1953, p. 103-109.

Continuous Casting of Nonferrous Metals

(*Continued from p. 114*)

work is best expressed in his own words: "Naturally, various types of continuous casting processes have their own particular problems, and the work described in this series of articles is appropriate only to some of the problems of the casting process in which the metal is solidified in a cooled cylinder. It was carried out on a laboratory scale, and was undertaken to study aspects of the continuous casting process relating to the successful operation of the process and the properties of the metal cast. It has shown that the ease with which the continuous casting process can be carried out is interlinked with the physical properties of the metal being cast. No attempt was made at a systematic investigation of any particular industrial process; the work aimed rather at establishing principles involved in the continuous casting process in the light of which individual processes employed industrially could be considered."

Sketches and tables are given to show the principles involved in the design of furnaces and machines. It is stated that, in general, it is desirable that the crystal growth in a continuously cast metal ingot should be, as far as possible, in a longitudinal direction. This requires a short mold with the water sprays placed close to the point of solidification of the metal. This removes much of the heat longitudinally. Such a method of cooling considerably restricts the amount of heat that can be removed in a given time and slows up production. The Asarco process operates on this principle for casting copper and bronze. Conversely, if faster operation is desired, cooling must take place in a predominantly radial direction. The mold length is increased and the result is a crystal growth more nearly radial. The Scovill process is an example of this.

The type of mold used in the author's experimental machine employs the radial cooling principle and the mold was nonreciprocating. The rate of cooling water was 500 gal. per hr., while the temperature rise was under 5° C. The ingot as it emerged from the casting mold was water sprayed. The steel liner was in

(*Continued on p. 118*)

Here's one you'll want to bite on!

It's Formbrite

FISH find this particular line of brass spinners so attractive that fishermen's demands have built annual sales of the Aeroplane Tackle Manufacturing Company of Denver to more than two million lures of all types.

The high finish on the spinner is part of the secret. While the cost of producing this is of no interest to the fish, it is to the manufacturer. Recently all brass orders were changed to Formbrite*, the superior ANACONDA Drawing Brass that has enabled this firm to cut polishing costs over 25%, and on several stamped products to produce the required finish by tumbling only prior to lacquering or plating.

Formbrite, with its superfine grain, provides a surface far superior to ordinary drawing brass. It is stronger, harder, more scratch-resistant than ordinary brass, yet retains remarkable ductility for forming and drawing. It's a premium product at a non-premium price. If these features lure you, we should like to show you how this better brass can cut your product's finishing costs. Or write for Publication B-39 to *The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario.*

Upper lure is Formbrite. Lower one is made of ANACONDA Fancy Pattern Embossed Brass.

Thirty-five years ago a fisherman, disgusted with his luck, cut up an old brass bait box to make himself a spinner resembling an old-time airplane propeller. Both fish and fisherman liked it so much, he started what is now a big and thriving business.

*Reg. U.S. Pat. Off.

FORMBRITE DRAWING BRASS

An ANACONDA® product made by The American Brass Company

Continuous Casting of Nonferrous Metals

(Continued from p. 116)

slight tension in order to minimize the possibility of bulging. In the "conclusion" of the first section of these articles, the author states that it has been demonstrated that the experimental laboratory machine provides a tool with which an investigation of the production and properties of continuously cast metal ingots can be carried out. Other problems would doubtless develop in large-scale operation, but the results obtained by the small machine may, in many instances, be applied to commercial practice.

The author next considers casting rate, mold surface and shape, and solidification rate. Also described are the different techniques used to continuously cast a variety of metals. Bottom pouring was used throughout and the usual degassing technique was employed. In the casting of lead and zinc, the stopper was removed and the molten metal allowed to run into a crucible placed beneath, until a steady flow was obtained. Then the crucible was removed and the metal flowed directly into the casting mold. Just after the metal began to enter the casting mold the downward movement of the dummy ingot was started. This rate of motion was gradually increased and then adjusted to maintain the level of molten metal in the mold about 1 in. from its top. The ingot being cast was keyed into the dummy ingot by means of a screw. Throughout the casting process there was therefore a positive pull drawing the ingot down from the mold. As a matter of fact, the ingot fell down from the mold under its own weight after the first part of it was cast.

Aluminum – It was not possible to continuously cast aluminum rod as a completely routine matter.

Copper – The process employed closely followed the method of Pell-Walpole and Kondic. The orifice for copper was 0.089 in. in diameter, accurately drilled and with the edges of the hole quite square.

Cast Iron – The water jets for cooling were replaced by nitrogen jets directed upward to prevent thermal shock.

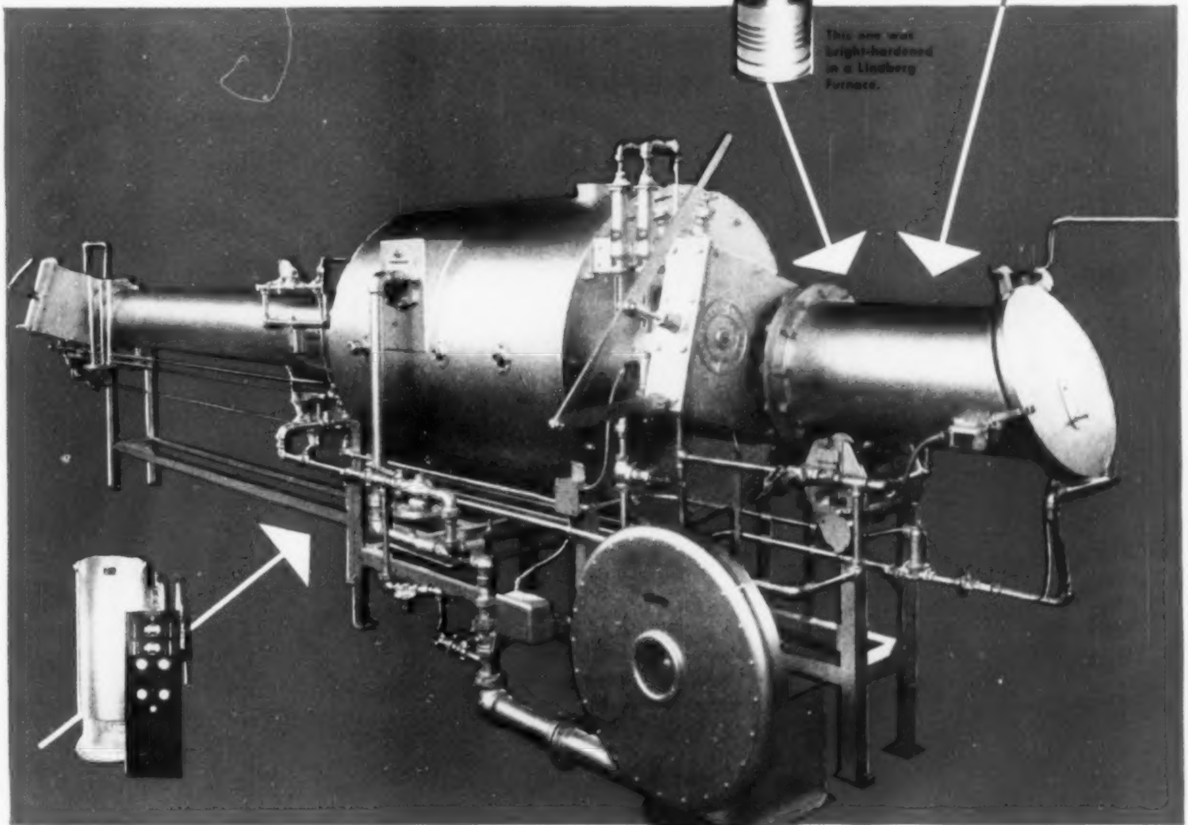
Steel – Only short ingots were

(Continued on p. 120)

HOW TO BRIGHT HARDEN AND ANNEAL STAINLESS STEEL!

This one was not bright hardened.

NO DOUBT ABOUT WHICH ONE HAS THE TONI!
(Apologies to Toni Co.)



If your production requirements call for the bright heat treating of stainless steel, completely free from oxidation and discoloration . . you'll want to know more about this amazing Lindberg Stainless Steel Heat Treating Furnace, many of which have been in successful use throughout the country for 4 years. They are *specifically designed* for the heat treatment of stainless steels and other high alloy materials.

This process eliminates the need for operations such as pickling, sandblasting, and machining . . which are not only costly and time-consuming, but also often disturb the delicate balance of the alloying elements on the surface of the metal.

Lindberg Stainless Steel Heat Treating Furnaces are built with purging chambers at *both* the charging and the discharging ends. This eliminates the chance of work chamber atmosphere becoming contaminated by either oxygen or water vapor . . which will oxidize stainless steel.

These furnaces use protective atmosphere supplied by Lindberg HYAM Hydryzing Generators. Atmosphere consists of dissociated ammonia (75% hydrogen and 25% nitrogen . . dew point, minus 60°F).

Your "Lindberg man" will be glad to tell you more . . call him.

LINDBERG FURNACES

Lindberg Engineering Company • 2448 W. Hubbard Street • Chicago 12, Illinois

Continuous Casting of Nonferrous Metals

(*Continued from p. 118*)

cast owing to the metal overflowing the mold in the casting process. The ingot diameter was 2 in. as compared with 1 in. for the other metals. A larger orifice had to be used to avoid solidification of metal at the rim.

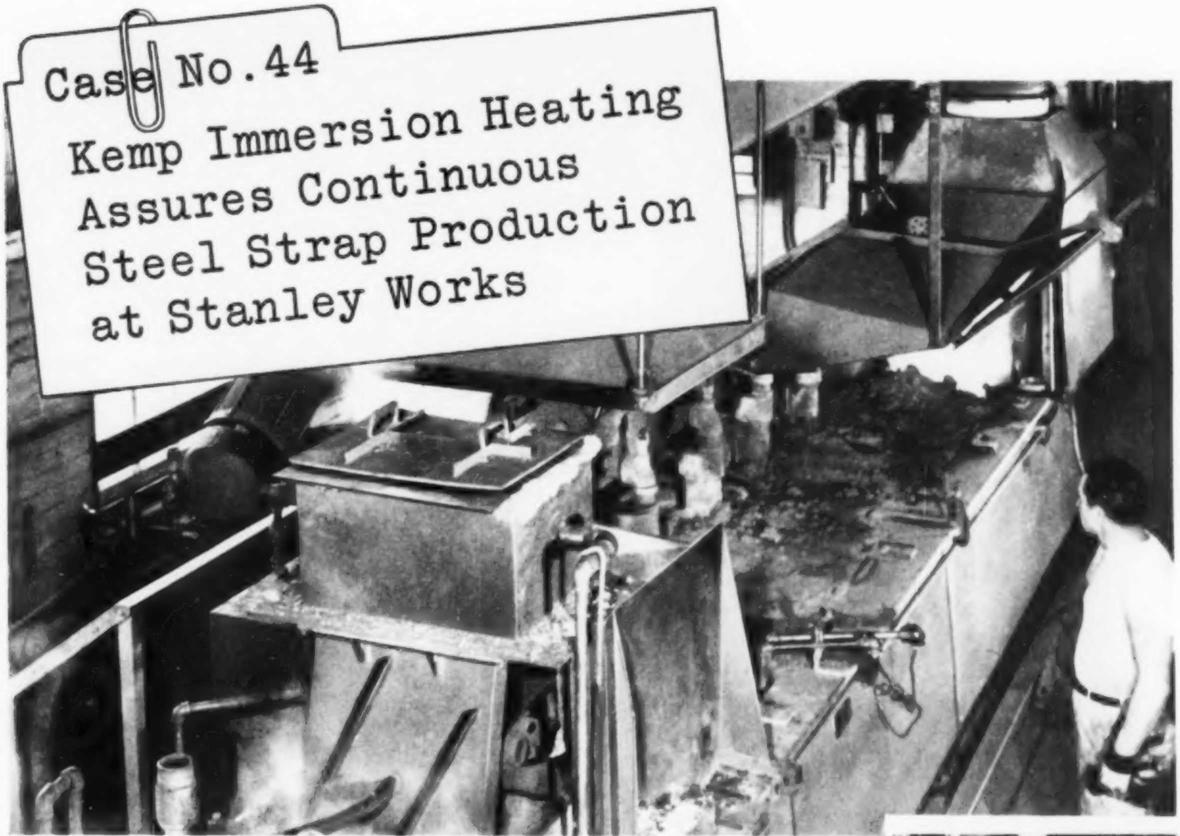
Bismuth Alloy – A eutectic alloy of 60% Sn, 40% Bi was cast so as to study the effects of its characteristic of expansion during freezing. A tapered mold was used and the casting was satisfactory.

The author goes on to deal with factors controlling permissible speed of casting, and attention is drawn to the fact that there is a maximum linear casting speed at which, using the conventional continuous casting arrangement, any particular alloy may be continuously cast. Because of the limited information concerning this, an investigation was made to find the factors and mechanism involved. Transverse fracture was found to be caused by: (*a*) the remelting of the first-formed solid metal skin as a result of heat being transferred to it from the interior metal; (*b*) definite tensile fracture of the metal skin.

In the course of the work, it was found that two types of fracture occur. In one type the fractured surface was visible and showed the characteristics associated with "hot tearing". The second was one in which the metal remaining in the mold flowed out after fracture. This caused a tube of metal to be left in the mold with the overflowed metal running out over the top of the fractured ingot. The first type was associated with a medium casting speed, while the second was found when fast casting speeds were employed.

Transverse fracture of the ingot was invariably found when low melting point metals were cast using silicone grease as a lubricant. Such ingots showed a well-defined line at the middle point in the length of the ingot between a smooth and roughened surface. This would indicate that fracture was due to direct tensile breakage of the first formed outer metal skin. In the upper part feeding occurred by direct pouring of a static casting, but in the lower half the metal had been fed in

(*Continued on p. 122*)



How Stanley doubled steel strap capacity overnight . . . slashed fuel costs, too

Rear view of Kemp Pot at Stanley Works shows gas feed lines, fire checks, and the Kemp Carburetor (left). Part of every Kemp installation, this carburetor assures complete combustion . . . without waste . . . without tinkering. Just set it, and forget it.

Today this bustling division of the famous Stanley Works at New Britain, Conn., turns out steel strapping on a 24 hour basis. Starting with raw, high carbon steel on giant spools, strap is semi-annealed, finished, coated and rewound again for shipping in one *continuous* process. New rolls of raw steel are simply spot-welded to the ends of rolls to eliminate any interruption.

Kemp Eliminates Bottleneck

From an output limited by the capacity of a gas underfired pot, production was doubled on the installation of a 32 ton Kemp Immersion Melting Pot. In addition, Kemp's *greater* heating surface, *faster* heat recovery, *lower* dross formation and *accurate* temperature controls meant real savings in fuel costs. In the words of Mr. Harold Heckman, plant foreman, "Through quicker heating of this pot, we are able to maintain production schedules." And unlike underfired pots, Kemp units eliminate open flame hazards and excessive room temperatures.

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KEMP OF BALTIMORE

Continuous Casting of Nonferrous Metals

(Continued from p. 120)

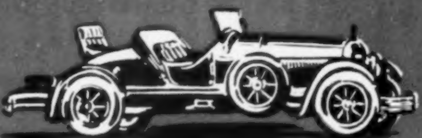
through a protecting solid metal annulus giving a smooth surface. Some of the other ingots did not reveal the two zones until the surface was macro-etched.

Freezing Range — The freezing range of an alloy is a controlling factor as to its suitability for continuous casting. Fracture occurs when the ingot has been restrained by some cause at some point in the mold. Metal that shrinks away from the mold surface requires no lubricant. Pure metals are easier to cast than their alloys, most alloys being prone to hot shortness; for these a lubricant may be useful. Every lubricant does not work equally well with every alloy. For example, silicone is useful for aluminum, but when it was used for an alloy of 60% Sn and 40% Pb, continuous casting was impossible; vaseline provided a good lubricant for this alloy. Also, a nonlubricated mold is better than one improperly lubricated. Summing up the problem of lubrication, it may be said that for the slow casting speeds used for ingots of large section, and for the higher melting point metals, lubrication is not important; the chill contraction of the metal on hitting the mold surface is sufficient to give adequate mold-to-metal clearance. For higher casting speeds lubrication is important.

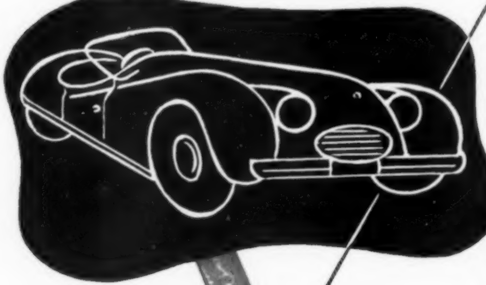
Hot Tearing — The metallurgical factors involved in hot tearing are: (*a*) the temperature range between the formation of the continuous network and the complete solidification of the alloy; (*b*) the strength of the continuous network; and (*c*) the ease with which the remaining liquid can feed between the primary constituents. It becomes evident, therefore, that the failure of a metal or alloy by transverse fracture during the continuous casting process is the result of the relationship of the ingot to mold clearance and the strength of the metal at high temperature.

Porosity — Density determinations and metallographic examination were used to determine the degree of porosity in the continuously cast ingots. This condition is considered as being due to a gas-metal type of reaction or to mechanical entrapment

(Continued on p. 124)



Other TIMES *Other* METHODS...



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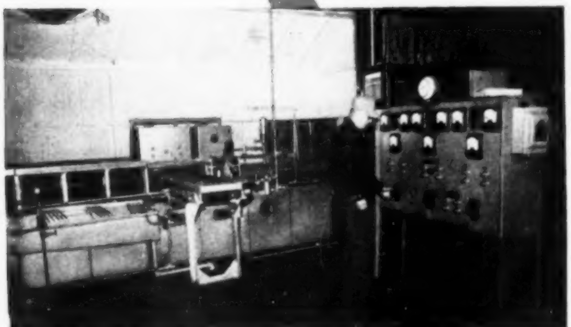

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Today's production methods require modern, low-cost, efficient equipment. For instance — a Morrison-Geco user writes as follows:

"Prior to the installation of Morrison-Geco dual frequency induction heating equipment, we used a fuel-fired furnace to heat billets prior to forging. The cost of fuel was 18.14¢ per billet. Now we heat billets at a cost of 8.15¢ per billet, on an 8½ hour shift per day. In addition to saving about 10¢ per billet, there is a saving of 1.73 pounds of steel per billet, which amounts to 12.85¢ per billet. There is also a further saving in personnel, since our induction heating installation requires 5 less operators than the fuel-fired furnace.

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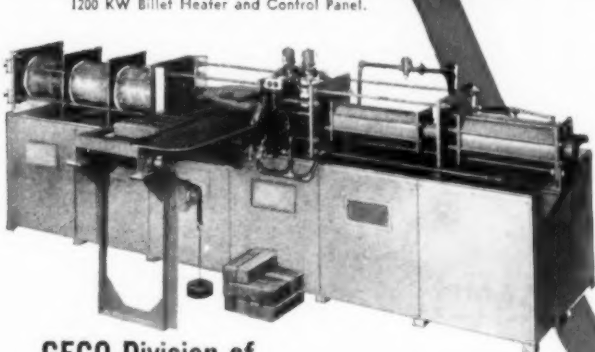

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Continuous Casting of Nonferrous Metals

(Continued from p. 122)

of gas and is closely associated with casting speed. It was found that casting rate also influences surface appearance and that better surfaces were obtained with higher rates. Detailed discussion is given of the "ripple" effect, and an attempt is made to correlate inter-ripple distance and linear casting speeds. The approach is largely mathematical.

The mass of detail contained in this report makes the abstracting of it difficult, and those directly interested are advised to consult the original articles. As one reads of the very numerous reactions involved in continuous casting one cannot but have admiration for those companies that, like Asarco and Scovill, are today turning out such large quantities of high-grade metal in various forms. It would be interesting if the author would do similar work on an alloy such as aluminum bronze which is forgeable at a high temperature, but forms aluminum oxide with celerity.

H. J. ROAST

Oxides of Zirconium*

THIS progress report describes efforts to study the growth mechanisms of the corrosion products on zirconium. Cathodic sputtering of zirconium onto a buffed copper foil resulted in some contamination of the film. The difficulties were eliminated by thorough cleaning of the surface of the copper before sputtering, but because the copper could not be buffed smooth enough, electropolished copper was used. Two other base materials were tried, glass and collodion on a glass surface. The films could not be removed from glass surfaces and collodion tended to produce discontinuous films.

It has been observed that the appearance of the white film on zirconium changes from a tenacious film to a flaky white deposit. Since it was desired to make an X-ray study of the nature of these oxides, stand-

(Continued on p. 126)

*Digest of "The Corrosion of Zirconium", by L. E. Colteryahn, W. Joseph, W. E. Ray and H. J. Read. U.S.A.E.C. report NYO-837, available from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Price 20 cents.

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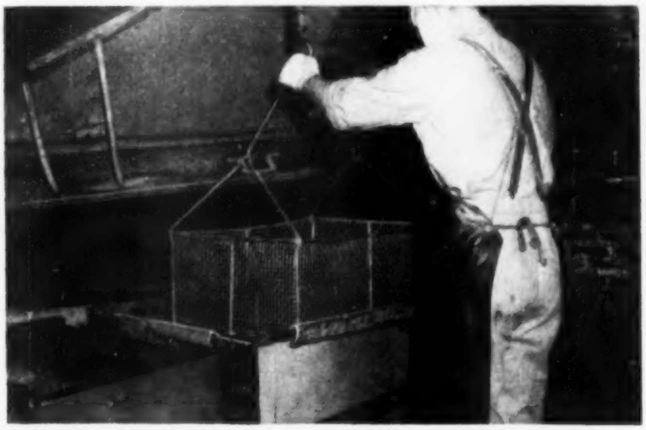
ALLOY TRAYS SAVE $1600 A YEAR— Pickling trays made of HASTELLOY alloy C have saved a company $1600 a year. The trays are immersed in hot 20 per cent hydrochloric acid and then into a solution of one per cent phosphoric acid with ferric salts at 205 deg. F. This treatment is used to produce a porous surface on metal parts. HASTELLOY alloy trays last two years. Other trays lasted only two months.



SIX YEARS IN HOT HCl—This HASTELLOY alloy B pickling tank has already outlasted other materials by four times. It is expected to be good for many years to come. The tank holds hot 15 per cent hydrochloric acid used to remove grease and lacquer from cast iron parts.

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•

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Oxides of Zirconium

(Continued from p. 124)

ards of the oxides first had to be prepared for comparison purposes because standard reference data were not available. Two different techniques for obtaining the oxides were used, precipitation with ammonium hydroxide and precipitation with sodium hydroxide. There was some indication that the oxide precipitated with ammonium hydroxide was a mixture of two different crystallographic structures. The oxides precipitated with sodium hydroxide were identical to those formed on pure zirconium when heated in dry oxygen and closely resemble those formed by water vapor.

To obtain information concerning the effect of water vapor on the rate of formation of the zirconium dioxide, iodide zirconium was tested at 1110° F. for 5 hr. in dry oxygen and in water vapor. The dry oxygen produced a black film on one half of the specimen and a loose white oxide on the other half. The specimen heated in water vapor showed a thick white oxide film which was easily removed to reveal a gray subsurface. The weight increase of this specimen was more than 50 times greater than for the one heated in dry oxygen. These experiments indicate that the reaction occurs directly between zirconium and water rather than between the zirconium and the oxygen formed by the dissociation of the water. The authors state that a possible reason for the water vapor increasing the corrosion rate is that the dioxide initially formed possesses a defect structure which enhances the reaction with water. Experiments are planned to study the semiconductor properties of the oxide to learn more about the mechanism. The reviewer believes that the erratic results on the specimen heated in dry oxygen also indicate that heterogeneity of the iodide zirconium should be examined.

A. D. Schwope

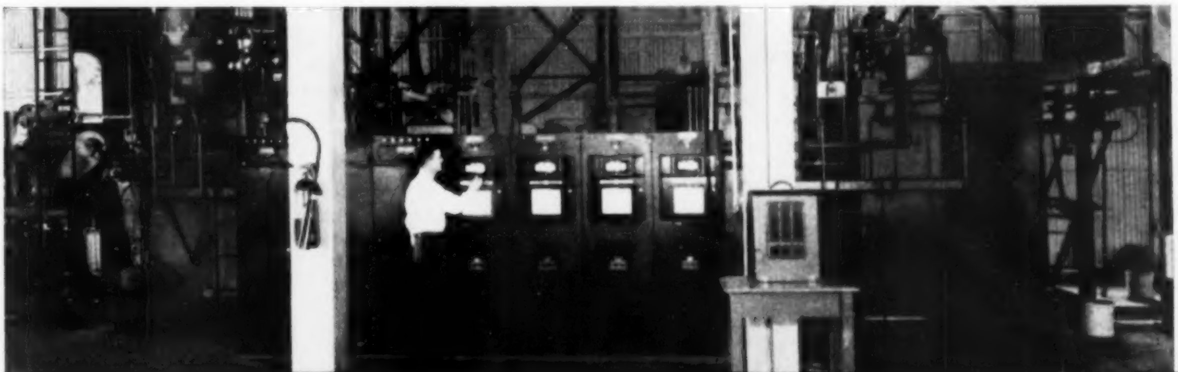
Corrosion Protection of Light Alloys*

The final results of an extensive series of outdoor exposure tests of some paint systems on aluminum and magnesium-base alloys and on steel are described. The various panels were exposed for 3½ years in marine, industrial and rural locations and to salt spray. Four different pigments were used in the primers, namely: zinc chromate, zinc tetroxychromate, iron oxide and red lead, with and without top coats.

At the marine station, the red lead primer, without top coats, showed considerable errosion; when top coats were used, there was crumbling of the entire film. Furthermore, red lead accelerated corrosion of the light alloys, particularly after the coating of red lead had begun to disintegrate from weathering. The iron oxide primer, without top coats, suffered marked chalking; this condition was prevented by the application of the top coat. It appeared to offer appreciable protection to aluminum alloys but little, if any, to magnesium alloys. Best protection to the light alloys was given by the zinc chromate and zinc tetroxychromate primers, the former being slightly preferable for use on the less

(Continued on p. 128)

*Digest of "Priming Paints for Light Alloys", by J. G. Rigg and E. W. Skerrey, *Journal* of the Institute of Metals, Vol. 81, 1952-53, p. 481.



Corrosion Protection of light Alloys

(*Continued from p. 126*)

corrosion resistant alloys. The top coat of aluminum paint having an alkyd base was better than the pyroxylin-base material. Except with red lead systems, all the light alloys were superior to mild steel.

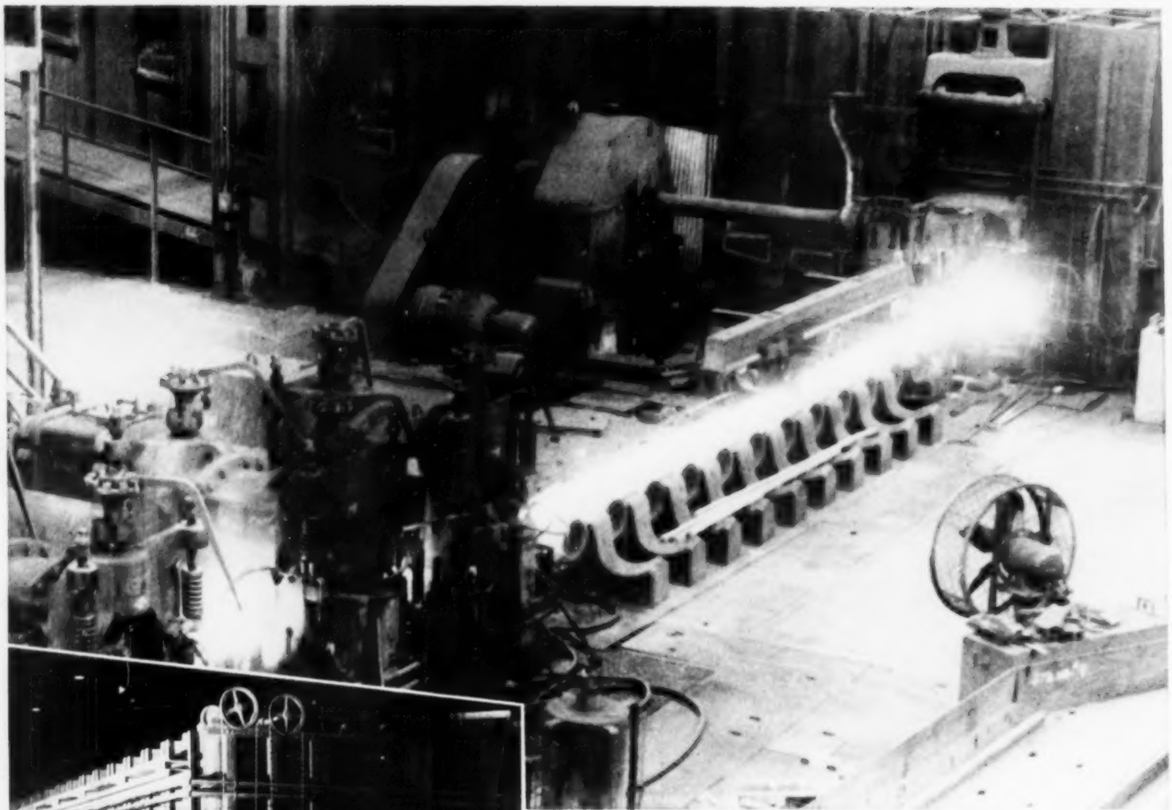
In the industrial location, red lead definitely accelerated corrosion of the light alloys before failure of the paint film. Red lead without a top coat ceased to protect mild steel after 12 months. Better results were obtained with top coats, but on the whole this system was inferior to those based on red oxide primers for the protection of light alloys. While the iron oxide primers were better, they failed to give protection without top coats; on steel, severe rust developed after 12 months. The addition of top coats gave considerable improvement. As at the marine station, zinc chromate and zinc tetroxychromate were better than iron oxide and red lead, either with or without top coats. With the exception of some erratic failure, systems employing these chromate primers gave satisfactory results. The light alloy specimens corroded much less than the steel specimens, whether painted or not.

Similar results were obtained in the rural location although, as might be expected, the extent of failure was somewhat less severe. The results in salt spray corresponded fairly closely to those in the marine atmosphere, although failure in salt spray was slightly less severe. This fact may be attributed to the greater severity of exposure at the marine station than had been anticipated.

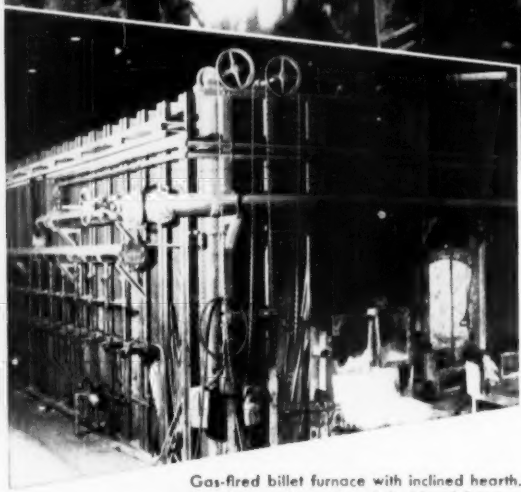
At all test sites, definite evidence of acceleration of corrosion of light metal was observed with single coats of red lead, while zinc chromate and zinc tetroxychromate primers gave outstandingly good protection.

The general conclusions reached were: (*a*) that red lead primers should be avoided on light metal; (*b*) iron oxide primers are satisfactory where corrosive conditions are not too severe; (*c*) zinc chromate or zinc tetroxychromate primers should be used on light metals for the most severe corrosive conditions; and (*d*) alkyd vehicles are superior to pyroxylin for aluminum paint top coats.

R. I. Wray



Hot billet goes through first pass after discharge from Gas-fired billet heating furnace.



Gas-fired billet furnace with inclined hearth. Gas burners located on left side of furnace, heat billets at lower end of hearth.

GAS provides the accurate temperature control for precision heat processing at Sheffield Steel Corporation

No other industry conducts more heat processing operations than the steel industry, and the use of GAS in the many reheating furnaces and heat treating operations at the Sheffield Steel Corporation has contributed to lower production costs plus higher efficiency in their plants.

For instance, the Sheffield plant in Kansas City produces a great variety of products, from staples and bolts to hot rolled bars and shapes. Throughout their production, from the making of basic steel to the finished mill products, GAS plays a major role in maintaining the accurate temperature control required. All ferrous and non-ferrous metallurgical heat processing operations must be carefully controlled, for just a slight deviation from the required temperature may throw the final results way off.

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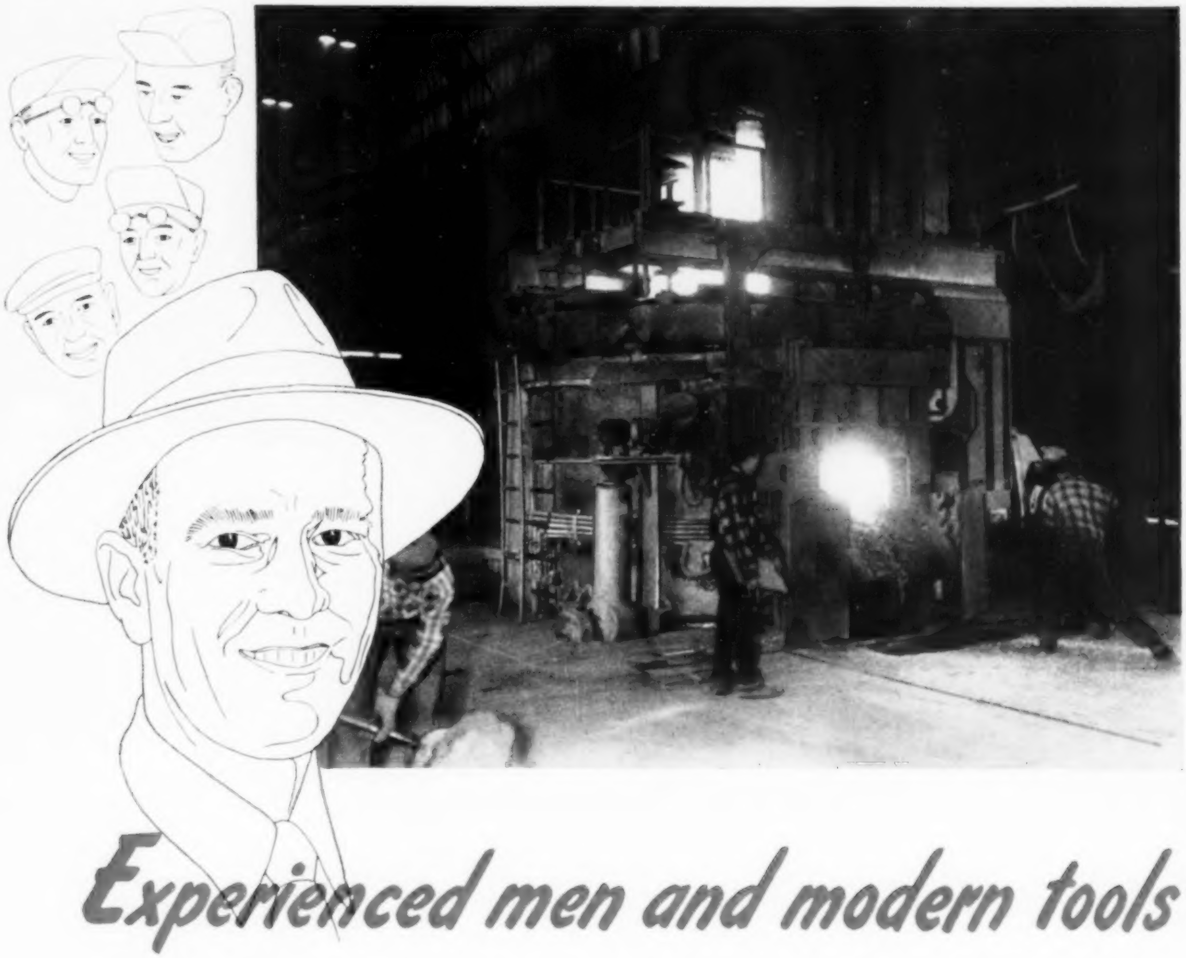


Quality Control in Metal Processing*

PRINCIPLES are more persistent in time than is practice, and a good deal more reliable. The purpose of this paper is to outline some of the factors underlying control of quality and to reduce promising lines for future research and development.

The technical control of processes is not an end in itself. At any one time within a company there is an optimum standard quality for a product. Control of quality in the region of this standard is economically desirable. Frequently schemes of instrumentation or recording are devised, apparently for their own sake, with only a vague and hopeful picture of how the quality or economy will be affected. Such a state is not regarded as control.

Quality has two separate, but not incompatible aspects. One concept regards quality as being measured on a scale leading to objective perfection without relation to uses or application. Second, quality may be linked to ultimate use, the criterion being fitness for purpose. In metallurgical manufacture the ideal standard is set by the intended purpose.

A simple example is a strip of metal produced for subsequent deep drawing. The quality of the strip is a function of its chemical composition, metallurgical structure and properties, surface condition, and its dimensions. All of these quantities (except surface) can be measured with precision and expressed numerically. If no method of physical measurement is available, the best that can be done is to establish standard examples and use them as guides for classifying the products on the basis of the judgment of the inspector. The best standard of quality for an individual article is the nearness of the strip to the standard expressed numerically. In case of a group of strips, the best measurement of quality is the mean and standard deviation of the dimension or quality characteristics of the individuals.

The cost of production is expected to rise steeply as the tolerances about the ideal dimension are narrowed, and will tend to level to a constant money value as tolerances are widened. This relation is termed the cost curve. The value to the customer is zero at some point just beyond the widest acceptance tolerance and usually flattens out as the ideal dimension is reached, so that narrower tolerances result in no increase in value. For all profitable production processes, the value curve and the cost curve intersect. The tolerance for optimum profit is at the point of greatest difference between value and cost.

For any process operating to fixed tolerances, there is an optimum rate of rejection which minimizes the cost of production per unit of acceptable product. Effort should be made to ascertain and then to attain this best rate of rejection rather than merely to attempt to decrease rejections to a minimum.

W. A. Shewhart's definition of control is used as a basis of further development: "A phenomenon is said to be controlled when, through the

(Continued on p. 132)

*Digest of "The Principles of Technical Control in Metallurgical Manufacture", by A. R. E. Singer, *Journal* of the Institute of Metals, Vol. 81, March 1953, p. 329-340.

Quality Control in Metal Processing

(*Continued from p. 130*)

use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future."

Uncontrolled processes will not continue of themselves to give a product of constant quality. Before process control is established, the causes of variation must be separated into assignable and random causes and the cause related to the effect. The next stage is to set up standards by defining the tolerance or limits within which the product may vary and yet remain acceptable.

The chief characteristics of four main methods of control are considered: automatic control, control by human operator, statistical control, and operational research. The particular feature of statistical control is the recognition of the part played by chance fluctuations in manufacturing operations leading to a procedure for dealing with them and for reaching definite conclusions despite their occurrence. Uncertainty is inherent in any data and is shown up clearly by, but is not derived from, a statistical analysis. The methods of operational research are not clearly described. Its broad objective, however, is commendable; this is to collect and analyze data obtained during manufacture or use of the product and to present the results as a basis for executive action.

It is concluded that advances in the control of quality will be made by extending technical control to cover more of the primary variables encountered in manufacture.

F. G. Norris

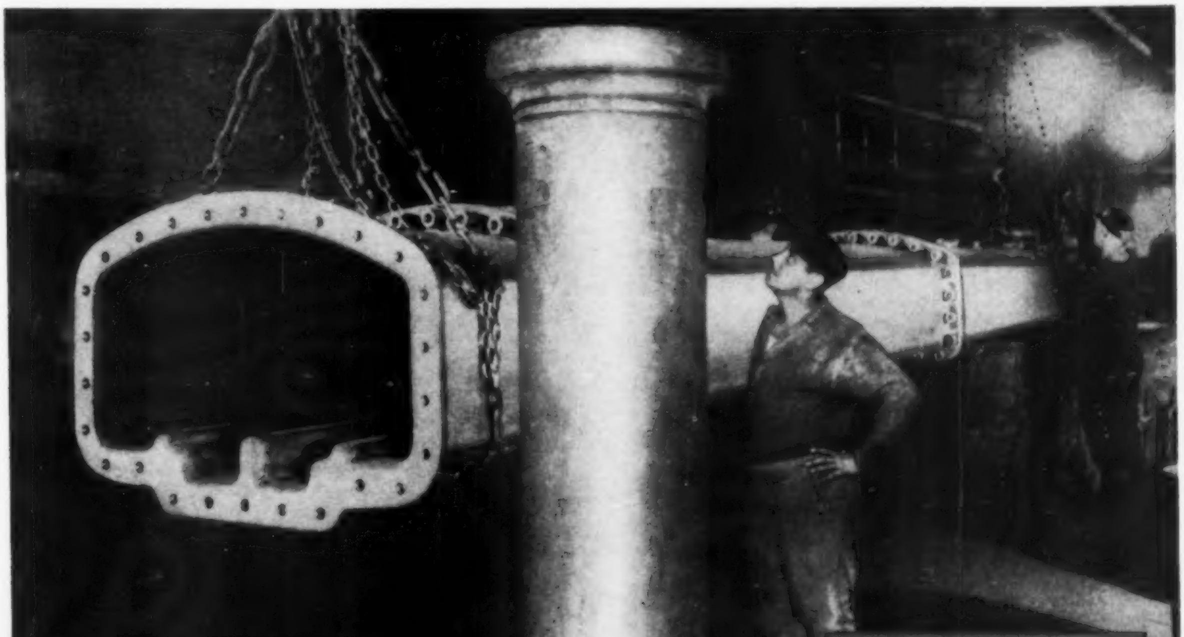
Four Approaches To the Study of Plasticity*

This paper was the 23rd Autumn Lecture of the Institute of Metals, presented at Oxford in September 1952. Professor Swift, from the University of Sheffield, is one of the outstanding engineers engaged in studies of metal forming processes. His unusual knowledge of industrial forming operations is supplemented by a keen insight into the nature of the physical process of slip within metal crystals, and by an understanding of mathematical analyses of macroscopic plastic flow processes. Among the attributes of the author is his unique ability to tell a complex story in an interesting and clear way. A quotation from the article will illustrate the lucid and humorous style of the presentation. In describing the technological skill involved in transforming a flat sheet of steel into an automobile fender in a single stroke of a press, the author says: "Neither the man who casually presses the button nor his mate who idly applies an oily rag at the right spot on the sheet has anything to learn from Charlie Chaplin in the matter of masterly nonchalance." The text is technically sound and cleverly written, with just enough humor injected at appropriate places to make the paper a pleasure to read.

The discussion of plastic properties

(*Continued on p. 134*)

*Digest of "On the Foothills of the Plastic Range," by H. W. Swift, *Journal* of the Institute of Metals, Vol. 81, November 1952, p. 109-120.



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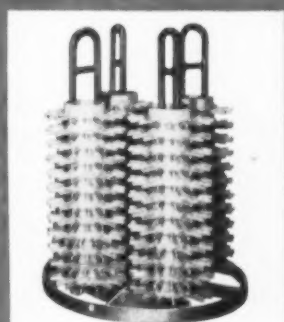

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Four Approaches To the Study of Plasticity

(*Continued from p. 132*)

is divided into four classifications—metallurgical, engineering, mathematical and physical—with the viewpoint of each being substantially different. The metallurgist and engineer are generally compelled to use empirical and trial-and-error methods; the metal physicist is concerned with developing an understanding of the nature and mechanism of plastic flow on an atomic scale; and the mathematician's interests in plasticity range from making analyses of behavior on an atomic scale to the macroscopic distribution of stresses and strains in a given material being formed in a specified manner.

The mathematician's approach is described, with historical references and developments being included for perspective. However, no complex or detailed analyses are included, because this paper was intended to describe the state of knowledge in a broad and general way. Enough examples are given, though, to show the present state of development.

The approach of the metal physicist is discussed, with the objectives of discovery of new materials, rationalization of predictions of the effects of mechanical or heat treatments, and planning of test procedures for plastic properties along more basic lines. The metallurgist and physicist are treated somewhat roughly by the author; that is, in discussing space lattices and unit cells he says ". . . the engineer . . . is not accustomed to deal in astronomical reciprocals, and the microgeometry of the space lattice is based upon techniques which have to be seen to be disbelieved". In discussing the model of a dislocation he says ". . . .the nodulus networks of knock-kneed knobs in which the metal physicist is apt to enmesh his students".

The engineering approach to the problem is treated with due humility. The general problem of analyzing stresses and strains during even simple forming operations is still beyond the range of the theoretical plastician. A deep drawn cylindrical shell was chosen as an example for illustrating approximate methods for calculating stresses, strains and punch loads. Even though the methods are approximate, the theoretical values agree remarkably well with actual measurements.

This paper is one that everyone interested in plastic flow should read—and those who take the few minutes required to do so will find it thoroughly enjoyable. E. R. PARKER

Thermocouples for 3400° F. Temperatures*

DURING casting operations carried out in the Ames Laboratory as part of a program of study of high-melting metals and alloys, it was found necessary to measure with some degree of accuracy temperatures up to approximately 2000° C. (3630° F.). Because of the nature of the metals these operations had to be done in either vacuum or inert atmospheres. Radiation pyrometers were found to be unsatisfactory in this work due to evolution of gases which cut down light intensity, and to formation of deposits on the sight

(*Continued on p. 136*)

*Digest of "High-Temperature Thermocouples" by H. A. Wilhelm, H. J. Svec, A. I. Snow and A. H. Danne, United States Atomic Energy Commission report AECD-3275, available from the Office of Technical Services, Department of Commerce, Washington 25, D.C. Price 5 cents.

Thermocouples for 3400° F. Temperatures

(Continued from p. 134)

windows. An alternative method of measuring these temperatures was to use a thermocouple, but the usual "high-temperature" thermocouples could not be used for the temperature range encountered in this work.

The tungsten-molybdenum thermocouple seemed to have considerable promise and was the first one investigated. The materials used were 16-mil tungsten and molybdenum wire obtained from the Callite Tungsten Corp. and double-bore beryllium oxide thermocouple insulators made in the Ames Laboratory. This thermocouple found considerable use in the high-temperature metallurgy of the laboratory, but since it possessed a very small emf. coefficient and reversed in sign in the region below 1500° C. (2730° F.), further studies were made to find a more suitable couple.

Couples were prepared from tantalum-molybdenum, tantalum-tungsten, columbium-molybdenum and columbium-tungsten for preliminary tests. Only the tantalum-tungsten and columbium-tungsten showed promise and calibrations were carried out on them. The tantalum and columbium wire was obtained from the Fansteel Metallurgical Corp.

In general, calibration involved the comparison of the test couple with Pt-Pt, 10% Rh thermocouple up to 3050° F., followed by a checking of this curve against melting points of pure metals. Metals used to check the comparison calibrations were Ag, Cu, Au, Pd and Pt. Melting temperatures used for these standards were in the order of 960° C. (1760° F.), 1083 (1981), 1063 (1945), 1553 (2827) and 1773° C. (3223° F.), respectively. The Ag and Cu were used in massive form; the Au, Pd and Pt in wire form and calibrations with the latter group were carried out by making a connection between the two thermocouple wires with a short piece of wire so that the melting point was to be observed as the wire was heated slowly. It was found that values within 0.1 millivolt were readily reproduced. The points obtained in this way agreed well with the comparison calibration and in addition gave a calibration point at

(Continued on p. 138)

The Park Neutra-gas Story:

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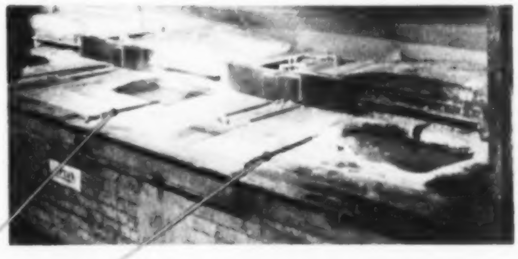
A patented development of Park's research laboratory, the Neutra-gas process efficiently and economically neutralizes chloride base salt baths . . . maintaining them free of de-carb in temperatures ranging from 1350°F. to 2300°F. The decarburizing oxides present are chemically converted back to chlorides by passing methyl chloride through the molten baths.

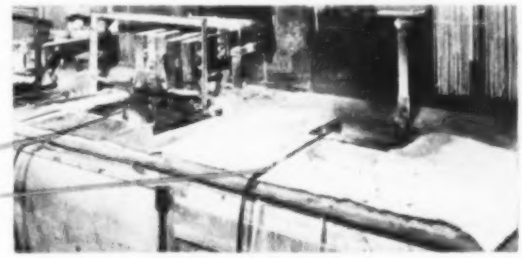
No solid rectifiers and their subsequent sludging are needed. No fresh salt additions are required except to replace drag-out. Fluidity of salt is maintained like new and sluggishness caused by solid rectifiers is eliminated.

Complete details of the Neutra-gas process plus valuable information on neutral salt baths, their operations and uses, are described in a technical bulletin available to you by mailing the attached coupon.

* Truly neutral chemically. Alkalinity can be maintained at zero.



At Commercial Steel Treating Corp., in Detroit, salt bath furnaces are daily cleansed of all impurities. Rectifying gas is bubbled into Park Nu-Sal Neutral Salt molten at its operating temperature of 1500°F.



Even high-speed hardening baths up to 2300°F. are easily maintained neutral. At Commercial, both pre-heat and high heat are rectified daily to zero alkalinity. Rectification is at 1850°F. in the high heat, done either on idling time or when furnaces are being used for hardening high carbon, high chrome die steels. Salt is Park Pre-heat 117, and Park High Heat 175-S.

Ansul Methyl Chloride (CH_3Cl) is a liquefied gas, 99.98% pure (by weight).

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Thermocouples for 3400° F. Temperatures

(*Continued from p. 136*)

1773° C. (3223° F.). Since heating to temperatures far above this point showed that no radical change in the nature of the curve for the Cb-W couple was evident, it was felt that the curve might safely be extrapolated to at least 1900° C. (3450° F.). Attempted calibration in the higher range using an optical prometer was not reliable because the correction factors were unknown.

Calibration curves were obtained for several lots of Cb wire, all coupled with a single lot of W wire. One calibration was found to hold for each lot of wire within ± 25° C. (45° F.); however, the difference in calibration between separate lots in some cases amounted to as much as 100° C. This is rather difficult to explain since the different batches of columbium were of the same purity and had the same treatment.

The fact that tungsten recrystallizes at high temperatures and becomes very brittle is a serious drawback. Junctions cannot be welded because the thermocouple then cannot be moved without breaking. It was found that a satisfactory junction can be made by tightly twisting the more ductile columbium wire around the tungsten for several millimeters and then tightly pinching the two together. To re-use the couple, the brittle portion is broken off and a new junction formed.

The couple was used regularly for quite some time in the Ames Laboratory and in pilot-plant operations and, although it possesses serious faults compared to the conventional low-temperature thermocouple, it is the best found up to the present time for the temperature involved.

G. M. Sinclair

Quality Control in the Production of Magnesium Alloys for Hot Working*

It is interesting to note the emphasis that has been placed by the authors upon the importance of conscientiousness and experience in the production and control of quality in melting and casting magnesium alloys. Their presentation is complete and detailed. From it, with only a working knowledge of magnesium melting and handling, one should be able to achieve castings of good quality.

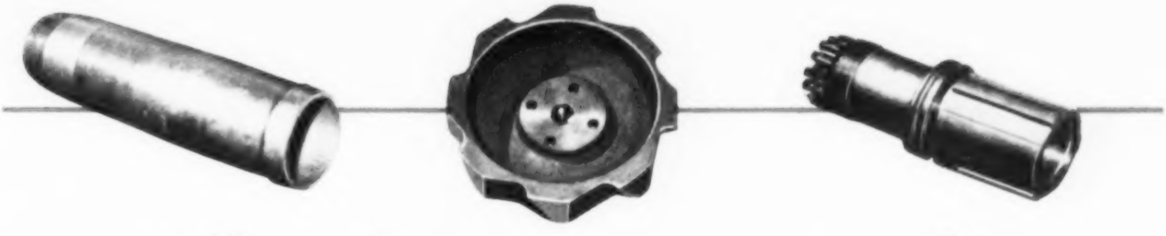
The close adherence in practice to the procedures described in this paper has provided a means to produce a material of very satisfactory quality, and has enabled them to maintain a rejection rate of less than 1% over a period of several years.

They melt the magnesium-aluminum-zinc-manganese alloys and chill-cast them into permanent "book" molds for extrusion and rolling ingot. High-stretch magnesium-zinc-zirconium alloys are poured by the semi-continuous direct-chill process.

An unusually intensive quality control program is necessitated by the fact that they are producers of

(*Continued on p. 140*)

*Digest of "The Control of Quality in Melting and Casting Magnesium Alloys for Hot Working", by R. G. Wilkinson and S. B. Hirst, *Journal* of the Institute of Metals, Vol. 81, March 1953, p. 393-400.



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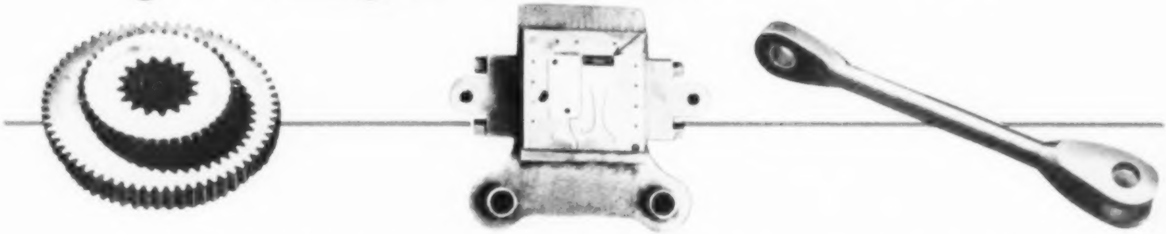

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Quality Control in the Production of Magnesium Alloys for Hot Working

(Continued from p. 138)

extrusion and rolling ingot to be fabricated by other companies.

The magnesium-manganese and the magnesium-aluminum-zinc-manganese alloys are melted in 4000-lb. cast steel crucibles. Charges consist principally of cell magnesium, run-around scrap and some secondary ingot. Manganese is added as manganese chloride. Melting and refining operations are conducted under the protection of fluxes that are dyed for identification and designated by letter. Completely alloyed crucibles are transferred to tilting furnaces where they are held at 1380° F. This metal is then poured into 300-lb. fabricated mild steel crucibles that are placed into gas-fired settings where they are flux-refined and the temperature of the melt increased to 1470° F. The melt is then cast into the mold. The mold is tilted to a position of 15° to the horizontal and is slowly raised to a vertical position during the casting operation. A hot top or top hat is used to supply feed-metal to the cooling casting.

"Careful observance of correct pouring temperatures and speeds is all-important for the production of sound stock."

Meticulous compliance to a sound, conscientious program of melting, alloying, handling and casting is their method of controlling nonmetallic inclusions and producing a reasonably uniform, fine-grained M alloy (AM 503).

It was learned while developing the magnesium-zirconium alloys that only an average product could be obtained if these alloys were cast into the conventional book-type mold. When these alloys were cast into book molds, there was incidence of outcropping microporosity resulting in internal oxidation and nitride formation during the prerolling soaking operation. The slow solidification rate of the book mold also contributed to the formation of zirconium segregation in the larger sized ingot.

In 1944 Magnesium Elektron Ltd. designed and constructed a small plant for direct-chill casting. Mag-

(Continued on p. 142)

Quality Control in the Production of Magnesium Alloys for Hot Working

(Continued from p. 140)

nesium-manganese and magnesium-aluminum-zinc-manganese alloys were readily cast without difficulty on the direct-chill unit. They then decided to utilize the machine for the production of the zirconium-containing alloys ZK 30 (ZW 3) and ZK 10 (ZW 1).

Their direct-chill machine consists essentially of three units for pouring, controlling and casting of metal.

The 300-lb. melts are prepared from refined magnesium ingot, process scrap and zinc. Zirconium is added as "master salt." A special "HE" (dyed blue) flux is used for ZK (ZW) operations.

The melts are poured from the crucibles into the mold either from a reservoir for rolling slabs and large ingot or simply down a launder for the smaller ingot. A tundish or stilling plate supported in the center of the slab or large ingot molds distributes the metal poured from the reservoir.

The molds are water-cooled sleeves, cooled by water rings–the number of water rings depending upon the mold length. Additional cooling is applied to the cast as it emerges from the mold.

The castings are withdrawn by a double acting hydraulic ram.

The use of vibration on the mold was tried and discontinued when they found an interesting banded concentration of zirconium segregation and the associated β-phase in their casting.

Flux inclusions are negligible with the use of the "master salt" and the dual-purpose barium chloride weighted "HE" flux.

Slices are taken from the top of the castings, milled and exposed to 80% relative humidity for 48 hr. to expose included flux. Oxide inclusions are revealed by pickling the croppings. Reflectoscopic examinations are conducted as a matter of routine for detecting internal cracking and oxide inclusions.

At Magnesium Elektron the functions of control and inspection are the responsibility of the metallurgical research department.

F. E. Robbins

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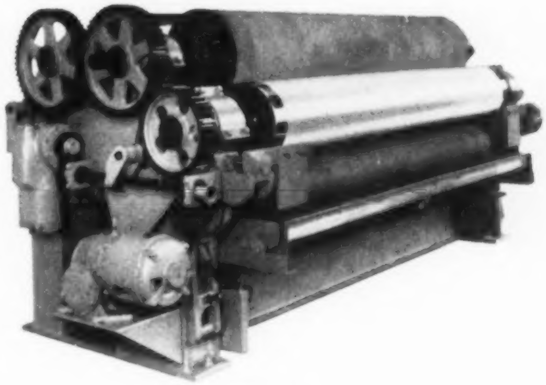

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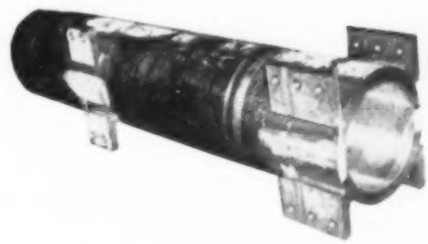

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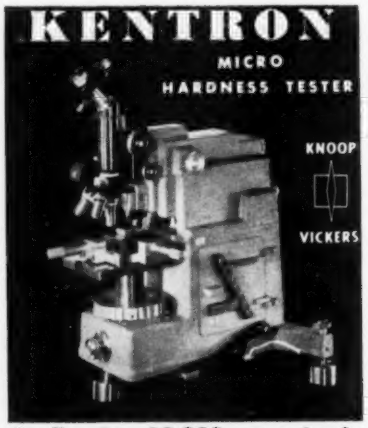

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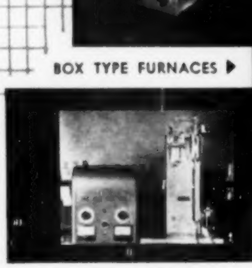

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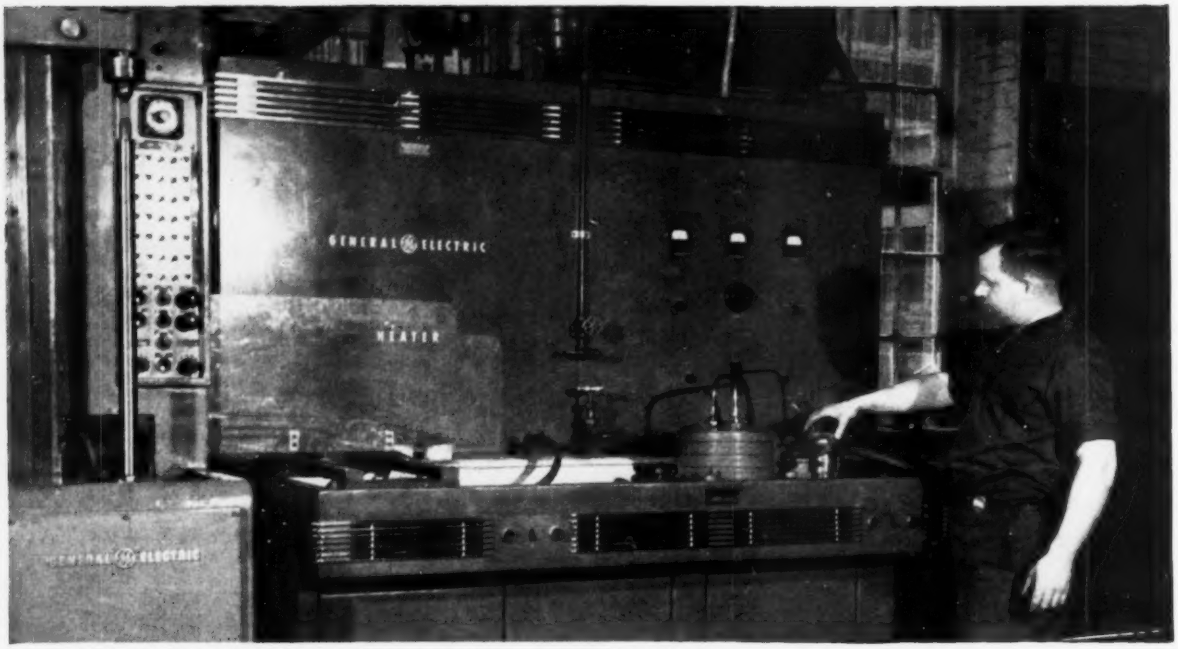

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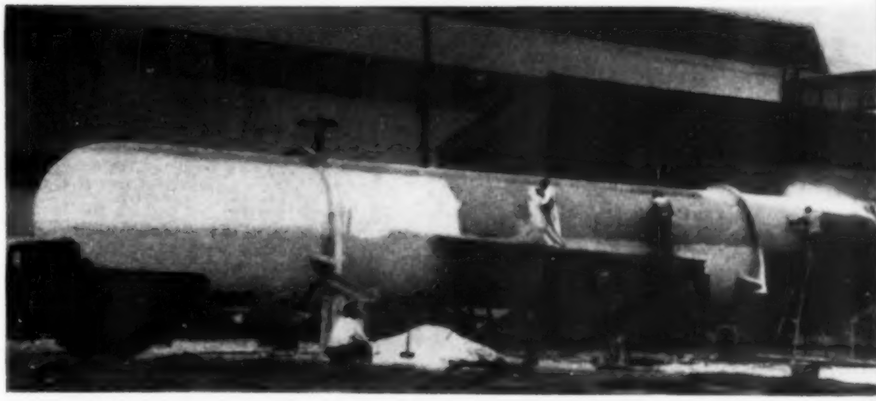


Fig. 1—High-Pressure Gas Tanks Metallized With 0.003 In. Zinc in 1932 Were in Excellent Condition in 1950. Only maintenance given was in 1941 when a few thin spots were touched up. Tanks are in a sea-coast atmosphere containing acid fumes from nearby refinery

Prevention of Corrosion by Metallizing the Surface

In spite of the fact that metallizing first saw the light of day back in 1908, very little is yet known about it by those not actively engaged in its use. Major American industrial organizations have taken advantage of the fact that molten metals can be sprayed onto dry surfaces and will stay there through stress and strain, yet many engineers are still under the impression that this process is new and unproven. The electrical manufacturing industries, the automobile makers, even the Army and the Navy, have been utilizing coatings applied by metallizing guns. Some have special departments headed by senior engineers. Many such organizations have conducted extensive studies to develop new uses, not only in maintenance, but in the design of major products.

Metallizing applications are roughly divided into two groups. First is the building up of relatively heavy coatings on machine elements, generally followed by machining, grinding or polishing. Whether a turbine shaft is to be sprayed with 0.25% carbon steel to restore the journal diameter, or a packing gland section is to be built up with stainless steel, the general technique involved is the same. The former is for a dimensional adjustment whereas the latter is to provide a corrosion-free surface.

The second class of work done is in the corrosion field. This generally refers to coatings of zinc or aluminum on iron or steel. This is the area of application that will be discussed.

THEORY OF CORROSION

In any discussion of corrosion and its mitigation, the theory of corrosion must first be agreed upon. Primarily as a result of work done by the National Association of Corrosion Engineers and by the Electrochemical Society, it is generally accepted that corrosion is electrolytic in action. This means that there must be present (in one form or another) an anode, a cathode, an electrical conductor between the two, and some sort of an electrolyte. High school physics has taught us that when dissimilar metals are immersed in an electrolyte and a galvanometer is inserted between them, a current will be indicated; one metal suffers degradation, while the other remains essentially

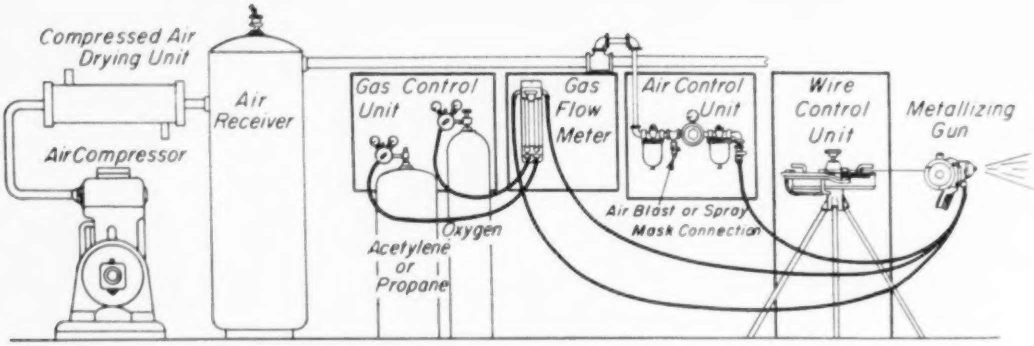


Fig. 2 – Typical Metallizing Installation. Compressed air is supplied at 40 cu.ft. per min. and 40 to 60 psi. pressure to spray the melted metal

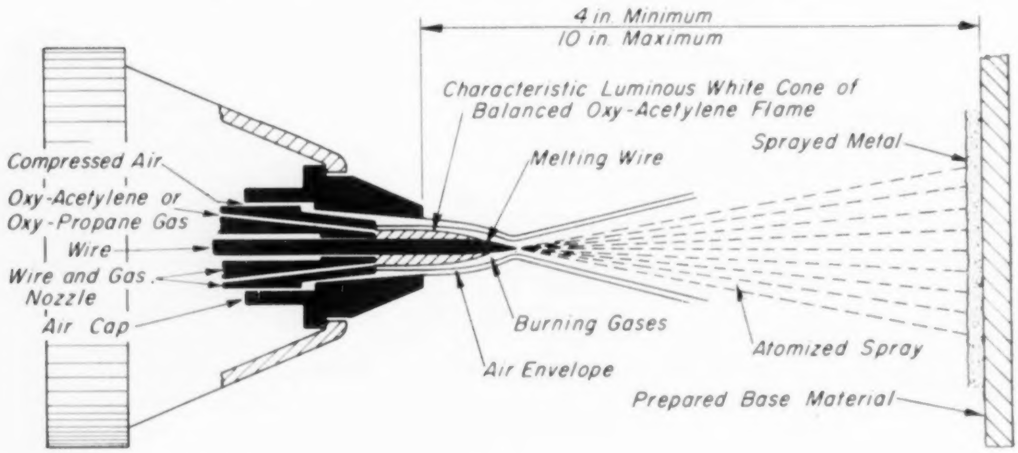
intact. The anode is the unfortunate partner; the cathode or the more "noble" metal is protected. Therefore, in the design of equipment subjected to corrosion, bimetallic arrangements should be avoided. Steel water tanks are certainly not bimetallic in construction; yet corrosion can and does cause millions of dollars worth of damage to them each year in the United States. The reason for this is simply that no steel or iron can be made without incidental inclusions of impurities. Once pitting corrosion has begun at such an impurity, the corrosion products themselves produce what is, in effect, an electrolytic couple. Mill scale on hot rolled steel is a notable example of a cathodic material electrically attached to the base material. A break in a continuous mill scale coating, exposing the bare metal underneath, can cause serious pitting in very short order. Even grain boundaries or residual stresses, as well as concentration differentials in the electrolyte, can set up a relative difference in potential.

The normal corrosion rate of steel or iron is not too dangerous. Pitting and localized attack are the culprits that produce leaks and weaken the structures.

There are essentially four methods of combatting corrosion. Number one is a barrier – an inert film – to isolate the electrolyte from the base metal. New plastic materials such as vinyls, rubbers and phenolics have done much to impede the advances of corrosion. These materials are highly resistant to moisture absorption and transmission, as well as being inert to many chemical reagents.

Second is substitution. The use of corrosion resistant metals or alloys as replacements for iron and steel is quite common. Stainless steel, nickel and Monel are representative. Here an attempt is made to produce a base metal which is capable of remaining intact although it is in

Fig. 3 – Cross Section of "Metco" Hand-Operated Metallizing Gun



intimate contact with the electrolyte. Use of such materials requires that careful consideration be given to the corrosion-producing electrolyte. For instance, all stainless steels are not resistant to all reagents. There is no "master" alloy. In general, their ability to resist corrosion stems from the film-forming ability of these metals. The theory of this mechanism is rather involved and it will serve no purpose to discuss it here.

The third means of corrosion protection is water treatment, or special treatment of the solutions causing the attack. Water treatment in boiler work is fairly well known in industry. Naturally, there is a limitation to the additives that can be used in most attacking liquids.

The fourth and perhaps newest means of corrosion prevention is cathodic protection. Cathodic protection means that the attacked metals, which are normally anodic, are artificially made cathodic by connecting an anode to the base metal, or by impressing a proper direct-current potential to the corroding material. In other words, the latter type of corrosion protection is a "reverse plating operation". Careful engineering and maintenance of a cathodic protective system can completely stop corrosion, provided only that the scheme can be made effective.

It is almost a trite saying in corrosion circles that no one method of corrosion mitigation can provide all of the answers. Many times, combinations of systems will approach complete immunity. For instance, in the protection of exterior underground pipe lines, cathodic protection would require rather high current densities (or potentials); however, when such pipe lines are painted, it is necessary to provide a minimum of power to protect the pipe at the breaks or voids of the paint film.

METALLIZING

Metallizing systems, as they apply to the prevention of corrosion of iron and steel, are unique in that they can provide in one treatment three of the four means of corrosion prevention—barrier, substitution, and cathodic, as will be explained later. In addition, because metallizing actually provides a film of metal, a harder surface is produced than with organics. This discourages abrasion which is often the initial cause of the breakdown of protective films.

Normal corrosion resistant surfaces are usually zinc or aluminum on iron or steel. The reason for this is that these two metals are effectively cathodic to ferrous metals. This accounts for the cathodic protection afforded by such coatings. Fairly

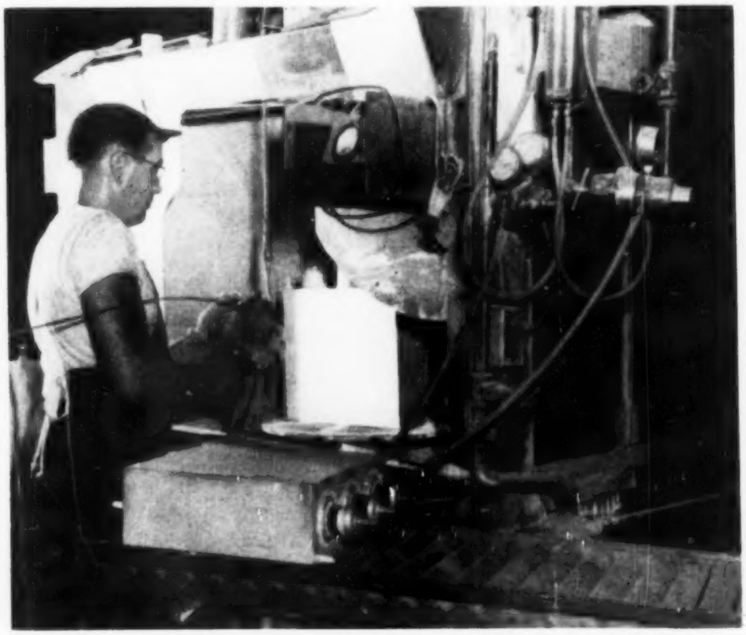


Fig. 4—Westinghouse Capacitors for Outdoor Installation Being Coated by Metallizing With 0.010 In. Zinc

Prevention of Corrosion by Metallizing

(Starts on p. 161)

thick layers are also easily laid down, whereas a coating of metallized stainless steel, nickel or Monel can only be applied on a water tank to a thickness of about 0.010 to 0.015 in. Heavier coatings require more elaborate preparations, pushing costs above a practical point, and if such a coating is perforated by mechanical abuse, a potential is set up between the base and the coating which will actually accelerate corrosion of the main body of the vessel. In other words, the corrosion resistant nickel-chromium alloys are anodic to plain irons and steels. Cathodic coatings should be avoided where only relatively thin films are obtainable.

Metallizing costs are initially higher than painting costs, so the layer must last longer and give a higher degree of protection. The following instances will indicate the high rating of metallization on both counts.

Perhaps the first known application of sprayed zinc still providing complete protection is on a lock gate in the St. Denis Canal in Paris, France. The most recent report from the Societe Nouvelle de Metallisa-

(Continued on p. 166)

Typical Coatings for Various Exposures*

General Considerations

Each specific application must be evaluated on the basis of the actual conditions to be encountered; therefore, the recommendations given herein are intended only as a guide in arriving at the final coating for a given job.

Atmospheric Exposure

Where galvanizing or similar methods are satisfactory, sprayed zinc 0.003 in. thick followed by one or two coats of chlorinated rubber or aluminum vinyl could be used.

Salt Atmospheres

For average salt atmospheres without salt spray present, zinc or aluminum 0.005 in. thick plus two coats of aluminum vinyl may be used.

For salt atmospheres where salt spray will be present, zinc or aluminum 0.008 in. thick plus one coat of proper primer and two coats of aluminum vinyl may be used.

Industrial Atmospheres

For industrial atmospheres, the use of aluminum is recommended exclusively since it provides much better protection against sulphurous gases (sulphur dioxide, hydrogen sulphide, etc.) and other gases encountered. For average industrial atmospheres, a coating of aluminum 0.005 in. thick plus two coats of aluminum vinyl may be used. For heavier industrial atmospheres, a coating thickness of 0.008 in. plus two coats of aluminum vinyl should be used.

Fresh and Salt Water Exposure

For exposure to fresh water having a pH value of over 6.5 and to salt water, only zinc is used, the coating thickness being 0.010 to 0.015 in. This is satisfactory only when the water temperature does not exceed 120° F. Zinc coatings also have some antifouling properties. In salt or brackish waters, one or two sealing coats of chlorinated rubber may be used.

For fresh water, where the temperature is not over 120° F. and where the pH is 4.5 to 6.5, 0.012-in. thick aluminum is used without sealing coats. For this application 99% aluminum should be used.

*From "Recommended Practices for Metallizing: Part IB—Application of Aluminum and Zinc for Protection of Iron and Steel", American Welding Society, 1952.

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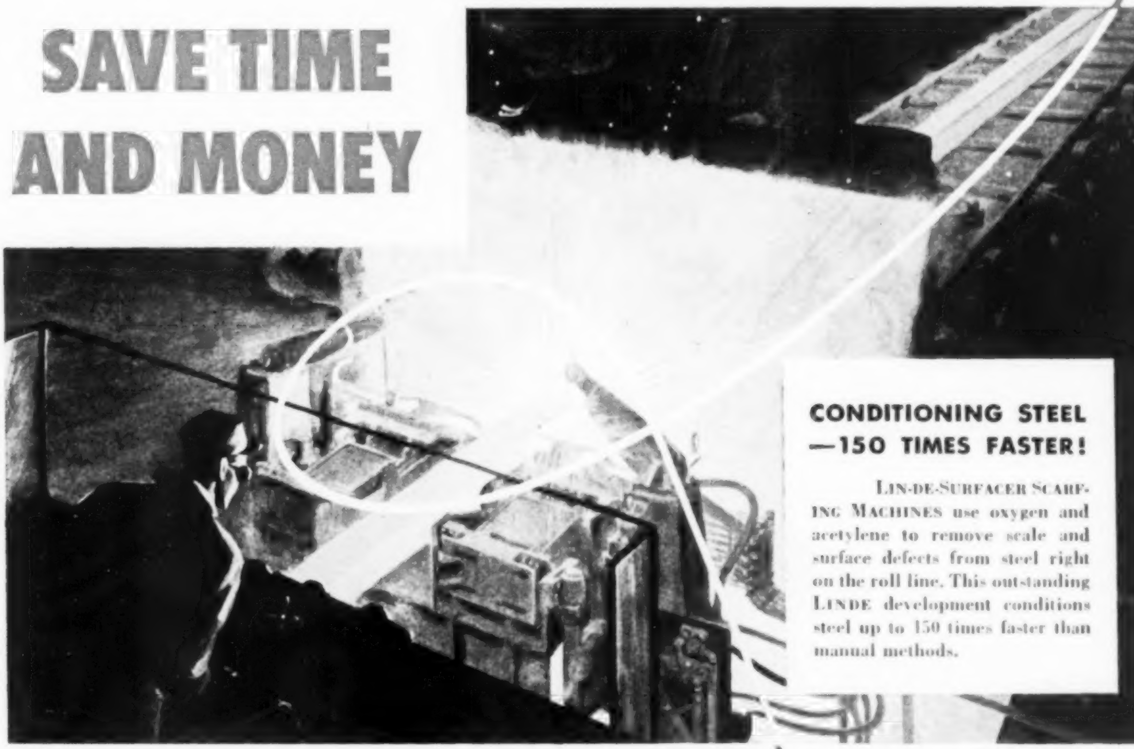

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Corrosion Prevention by Metallizing

(Starts on p. 161)

tion indicates that, though never painted, there is no rust.

Twenty years ago, one of 14 coal barges operating in the Delaware River at Philadelphia was treated with a metallized coating of pure zinc on the hull as well as the interior of the cargo holds. This barge is still operating with practically no maintenance required by corrosion, although it was not a new vessel when first treated. Subsequently, 14 other vessels were similarly metallized. The ice and trash conditions on the Delaware River have actually worn off the zinc in areas at the waterline and under the bows of some of these barges. At these points, additional zinc has been applied. The work has been successful to the point that the owners consider it essential to the economical operation of their equipment. Perhaps if the modern practice of applying heavier coatings of sprayed metals at the area subjected to heavier abrasion had been followed, no additional maintenance would have been necessary in this 20-year period.

The Riverhead Water District in New York provides another bit of evidence which is similar to an example of metallizing in Pennsylvania. The interior of the Riverhead elevated water storage tank and the hull of a tugboat were both metallized some 18 to 20 years ago. Rather thin coatings of zinc were applied, since the guns sprayed slowly in those days. After 15 years, both the tug hull and the water tank were completely protected from corrosion, yet inspection two years later indicated that no zinc remained!

This termination of protective life is explained as follows: The life of protection afforded by any anodic metallic coating is a function of its thickness or weight. In both the tank and tug, steel eventually was exposed at the thinner areas. Each additional square foot of newly exposed steel threw a greater load on the remaining zinc anode. Because this bare steel was being protected by the sacrificial action of the zinc, the rate of dissipation of the zinc increased with the increased area of cathodic steel. *(Cont. on p. 168)*

Corrosion Prevention by Metallizing

(Starts on p. 161)

The foregoing hypothesis is substantiated by tests that were made by two major shipyards some 15 years ago. Simultaneously two yards tried zinc metallizing on test panels on the bottoms of rather large ships. These areas, though large, were small compared to the uncoated surface. After a relatively short time, the vessels were drydocked and it was noticed with some disappointment that all of the zinc had disappeared. What was not realized at the time was that during the period that the zinc was still active, it was providing cathodic protection to the surrounding steel. Undoubtedly these same ships carried zinc plates under the sterns and probably these were replaced during the drydocking period. Evidently no concern was felt over the loss of zinc plates although the loss of zinc metallizing was viewed with some raised eyebrows. To effectively prevent corrosion below waterline it is necessary to treat the entire area. Small breaks in the film, which expose very small areas of steel cathode, are not damaging, for these small areas are very effectively protected by the overwhelmingly large area of anodic zinc.

It is estimated that in the United States alone some 300 ships have been treated with metallizing systems. Abrasion of hulls by docking or by flotsam is paralleled in other industries. Elevated water storage tanks in the northern states will freeze over in the wintertime and as the water level rises and falls, an ice "plug" scrapes against any protective film. Even if this does remove some zinc, the remaining coating cathodically prevents corrosion of the exposed steel. The Erie Water District in Northern Pennsylvania has had some interesting experiences with metallizing going back 20 years. One involved leaky filter troughs. It was decided to try zinc metallizing to stop the leakage and to maintain the troughs until new ones could be installed. Today, over 18 years later, those same troughs are in use.

The Panama Canal Zone Authority has studied protective systems to be used on lock gates in tropical en-

(Continued on p. 170)

Corrosion Prevention by Metallizing

(Starts on p. 161)

vironment. After laboratory exploration, several promising coatings were applied. Ten years later a report in *Corrosion* concluded:

1. The systems which show outstanding performance are those metallized with zinc.

2. Zinc metallizing provides a sacrificial prime coat which acts as secondary protection if and when the organic top-coats have deteriorated or become damaged.

3. Zinc metallizing is not considered justifiable if the length of the service period is relatively short—for example, four or five years—and regular maintenance repairing or repainting is the rule at the end of such relatively short periods.

SPRAYED ALUMINUM

Severe corrosion problems exist in the maintenance of contact sulphuric acid plants. Monsanto Chemical Co. and Leonard Construction Co. have jointly developed a specification that has become standard procedure in the manufacture of equipment for these conditions.

In the converter, the hot heat exchanger, and piping connecting these units, the steel is exposed to temperatures ranging from around 850 to as high as 1150° F. The equipment contains a gas composed of up to 10% or more SO_2 which, enroute, is converted into a mixture of SO_2 and SO_3 at the high temperature. Bare steel tends to "scale", and while this is not at all serious from the point of view of converter life, some scale drops off into the catalyst pellets and increases resistance to proper flow of the gas.

Metallizing with approximately 0.010 in. of aluminum very materially stops this scaling. How long the job will last is not known, but it is well worth it if metallizing needs to be done even as often as six-year intervals.

Organic paints do not hold up under high temperature on such equipment as exhaust manifolds, mufflers, and smoke stacks—even in more conventional industries. It is standard procedure at Bethlehem Steel Co., for example, to metallize

(Continued on p. 172)

Corrosion Prevention by Metallizing

(Starts on p. 161)

the exteriors of smoke stacks and waste heat exhausters with aluminum. Mufflers on Cooper-Bessemer gas engines are similarly treated. Some of this work has been done for over 20 years.

Recent investigations into the use of silicone-aluminum paints have discovered that thinner layers of sprayed aluminum will serve as undercoats if these organic materials are painted or brushed over the sprayed metal. It is a question as to whether these paints remain stable at elevated temperatures; however, it is conceded that even though the vehicle may burn out, the heavy pigmentation remains in the pores and irregularities of the sprayed coating, thus extending its total life.

COMPLEX COATINGS

It should be mentioned here that there are two patented processes known as "Metcolized"* coatings, which use nickel-chromium sprayed metal with or without a subsequent coating of sprayed aluminum. In environments where these systems are used, the initial heat will fuse the sprayed coatings to the ferrous metals, creating solid intermetallic solutions on the surface. The nickel-chromium alloy is applied for temperatures ranging around 1800° F., and the nickel-chromium plus aluminum is for similar environments containing sulphurous compounds.

Bethlehem Steel Co. has set up a department to apply "Metcolizing" to annealing covers used in the heat treatment of strip or wire in the Sparrows Point plant in Maryland. The covers are made of inexpensive mild steel and sprayed on the exterior surface.

The glass-lined tanks widely used in the manufacture of beer, food and chemical products often are damaged through mechanical abuse or accident. When the glass coating is ruptured it is usual procedure to use metallizing guns to spray small quantities of tin or other corrosion resistant metals—sometimes even gold, silver, molybdenum or platinum—on the crazed areas.

*Registered, U.S. Patent Office.

The following, because of its importance in the consideration of metallizing, bears repeating. In ordinary corrosion, such as that found in fresh water, polluted water, and salt water, and in rural, industrial and seashore atmospheres, zinc or aluminum is generally covered with organic coatings. Where environments are encountered which would rapidly attack these white metals, stainless steel, nickel, Monel and other metals can be used, but as these are inherently cathodic to steel, special consideration must be given to their application and use.

Although metallizing was first used more than 40 years ago, it has only recently gained general acceptance. This is primarily due to the development of faster and more efficient metallizing equipment. Faster metallizing means more economical metallizing. This, coupled with the increased labor rates for union painters, has brought metallizing to a position where it is frequently more economical to metallize than to paint, the only qualification being that long-life protection is desired.

High-Temperature Fatigue*

In the operation of gas turbines at high temperature, the stress conditions may be such that both fatigue and creep of some of the components occur. This is especially true for the rotating turbine blades. These two properties should be considered together for a proper appreciation of the reaction of metals to the stresses that are likely to arise in gas turbine operation.

At room temperature, steels and some other metals possess definite fatigue limits which are independent of the number of stress cycles and are little affected by the speed of cyclic change of stress; no such definite limits are found at high temperatures—that is, the curves don't usually have a "knee". Alternating fatigue stresses at high temperature are therefore normally recorded as the stresses producing failure in a particular time, or at a specified number of stress

(Continued on p. 174)

*Digest of "Fatigue at High Temperatures", by H. J. Tapsell, Symposium on High-Temperature Steels and Alloys for Gas Turbines, British Iron and Steel Institute, February 1951, p. 169-174.

High-Temperature Fatigue

(Continued from p. 173)

cycles, such as stress for failure in 10^8 cycles.

In practice, the cyclic stresses are usually superimposed on a static stress, and creep may accompany fatigue. If the stress is small in relation to the cyclic stress, creep will be small or negligible and failure will be by fatigue, but with high static stress, creep is the predominant factor leading to failure in a time mainly determined by creep properties. At high temperatures under vibratory stress the number of cycles to fracture is a function of the cyclic speed; the time factor, therefore, arises in an additional form. The magnitude of the effect of cyclic speed has not been studied by the author for increasing values up to the resonant vibration speeds of turbine blades, but the evidence so far obtained at lower speeds suggests that the fatigue strength for a fixed number of cycles at resonance speeds is somewhat higher than at the normal (slower) laboratory testing speeds of about 2000 to 10,000 cycles per minute.

When a component is subjected to alternating bending stresses, their magnitude may be sufficient to produce plastic strain in the most highly stressed fibers, causing stress redistri-

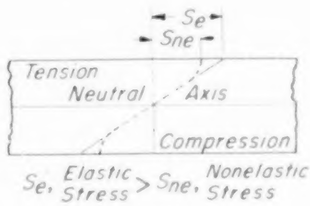

Fig. 1—Stress Redistribution in a Component Subjected to Alternating Stress. Solid line represents linear elastic distribution; dashed line represents when plastic flow occurs

bution across the section. A typical stress redistribution might be as shown in Fig. 1, wherein the solid line indicates linear elastic distribution and the dashed line the distribution if plastic flow occurs. The nature and extent of the redistribution will depend on the form of the stress-strain relation determined at the same loading speed as the alternating cycles. *(Continued on p. 176)*

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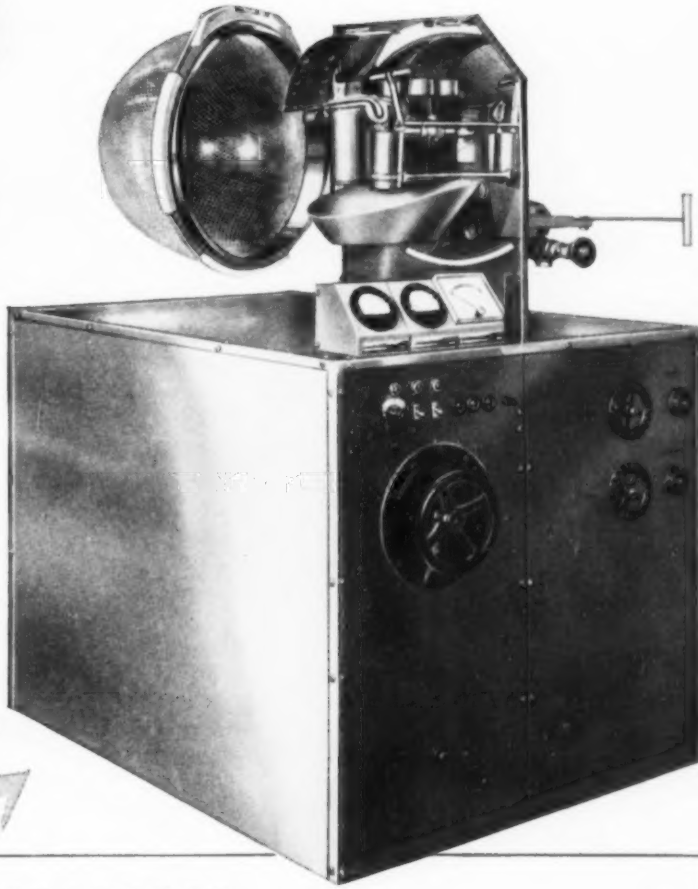

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High-Temperature Fatigue

(Continued from p. 174)

Under alternating direct stress, when the maximum stress of the cycle exceeds the elastic limit, a hysteresis stress-strain loop is developed representing work done. With a rectangular beam of material under alternating plane bending at constant maximum strain, each fiber strained beyond the elastic limit develops a lower stress than the nominal value, $S_{ne} < S_e$. When the cyclic frequency is increased, plastic strain has less time to develop and the stress in the outer fibers strained beyond the elastic limit, S_{ne}, more nearly approaches the nominal value, S_e; that is, the actual stress is higher. The hysteresis loop correspondingly decreases in width as the cyclic speed increases, and there is less work done on the material per cycle. The relationship between the work done per cycle and the number of cycles to fracture is unknown. It may be assumed, however, that under alternating stress cycles, the number of cycles to fracture will depend on the cyclic speed but is unlikely to be a direct function of the speed. The relationship is probably approximately logarithmic, as has been found for mild steel at 400° C. (750° F.).

At very high cyclic speeds there is little time for plastic yielding at the maximum stress of the cycle; therefore, the actual stress for a given deflection or bending moment is probably very close to the stress computed from an elastic formula.

Since the maximum fiber stress in bending may be distinctly less than that based on an elastic state of distribution, a material undergoing alternating bending may appear to withstand a higher (nominal) stress for a given endurance than when subjected to alternating direct stress. In gas turbine blades, however, the speed of alternating bending is so high (60,000 cycles per min.) that the bending stress may be very close to the computed elastic stress.

Data are presented for the fatigue and creep properties of five alloys, Rex 78, Nimonic 80, G18B, G32, Rex 337A, at temperatures from 600 to 800° C. (1110 to 1470° F.) for times from 10 hr. to, in some instances, in excess of 1000 hr.

(Continued on p. 178)

COMPLETE *Finishing* SYSTEMS

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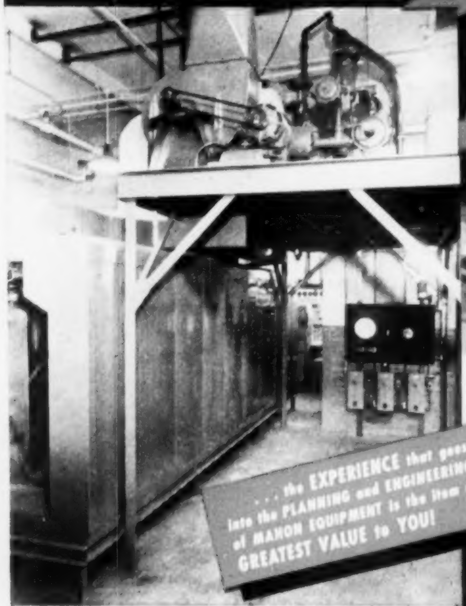
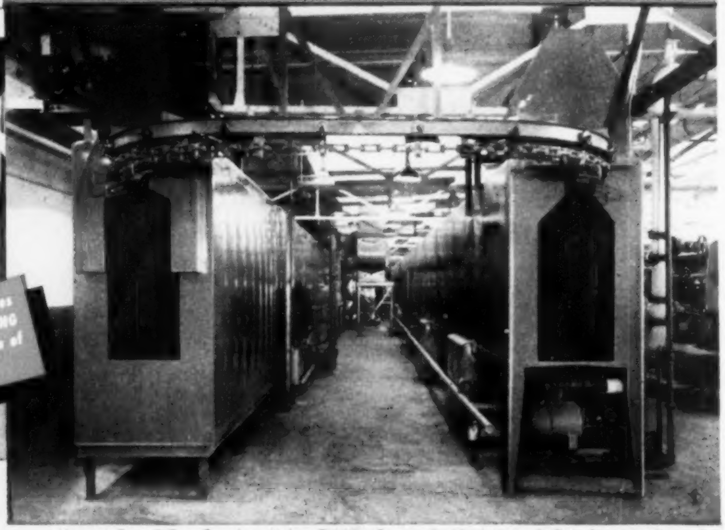
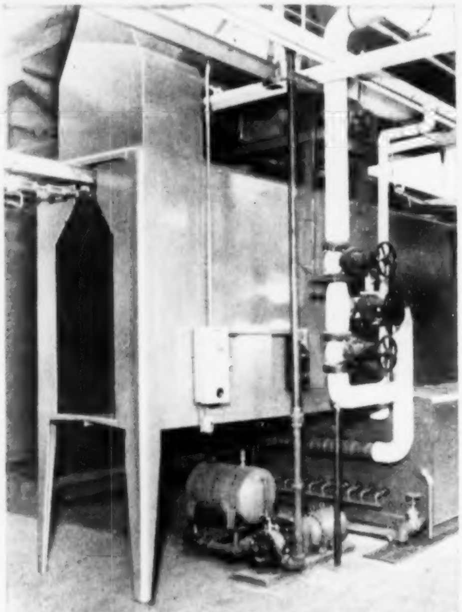


Mahon Low Temperature Finish Drying Oven at American-Standard. View shows Heating, Recirculating and Exhaust Equipment as well as the Control Cabinet Housing Temperature Controls, Recording Instruments and Safety Devices.



View of One of Two Complete Mahon Finishing Systems Installed in the Buffalo Stamping Plant of American-Standard. Metal Cleaning and Rust Proofing Machine and Dry-Off Oven are in the Foreground.



Exit End of Mahon Metal Cleaning and Rust Proofing Machine at American-Standard. Processing Solutions are Heated by Steam. Temperature Control is Automatic.

HEATER PANELS at AMERICAN STANDARD are also FINISHED in MAHON EQUIPMENT!

Major elements of a second Complete Mahon Finishing System installed in the Buffalo Stamping Plant of American-Standard are illustrated here. This second system, like the other, is ultramodern in every respect. Parts are carried on a single conveyor which passes through a five-stage Metal Cleaning and Rust Proofing Machine, a Dry-Off Oven, a Cooling Tunnel, two Conventional Type Hydro-Filter Spray Booths which are staggered right and left hand, for spraying opposite sides, and finally through a Low Temperature Finish Drying Oven. This is another typical Mahon Finishing System designed to do a specific job efficiently and economically. If you have a finishing problem, or are contemplating new finishing equipment, you will find that Mahon engineers are better qualified to advise you on both methods and equipment requirements . . better qualified to do the all-important planning, coordinating and engineering of equipment—which is the key to fine finishes at minimum cost. And, you will also find that Mahon equipment is built better for more economical operation over a longer period of time. Mahon's background history in this highly specialized field covers thousands of Complete Finishing Systems including Dip, Flow Coating and Spray Equipment for every conceivable product painted on a production basis. See Mahon's Insert in Sweet's Plant Engineering File, or write for Catalog A-654.

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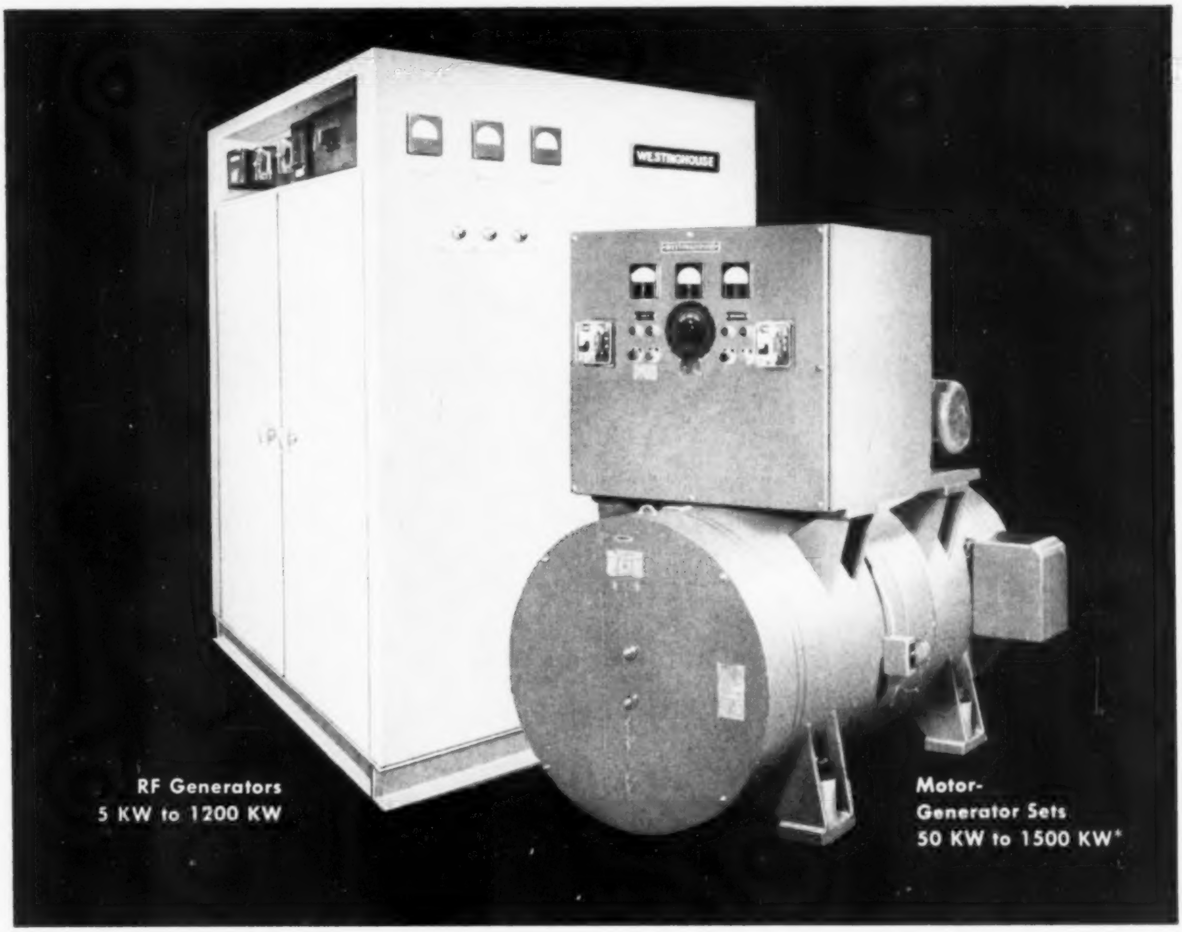

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High-Temperature Fatigue

(Continued from p. 176)

A method is presented to correlate fatigue and creep data into composite diagrams for design use where static and vibratory stresses appear in combination. A typical fatigue-creep diagram, for Nimonic 80 at 700° C. (1290° F.) and a time of 200 hr., is given in Fig. 2. The curve ABCDE shows various stress combinations to give fracture in 200 hr. at 700° C. Point E is pure creep failure, no vibratory load, and point A is pure fatigue failure, no static load. Com-

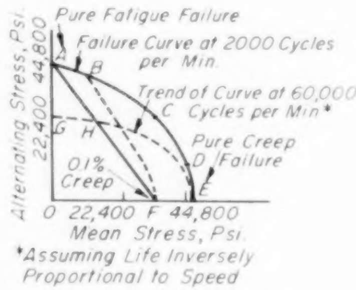

Fig. 2 – Fatigue-Creep Diagram

binations of static and vibratory stresses to give fracture time of 200 hr. are on the curve between A and E. The point F represents the tensile stress that, if applied alone, produces a definite amount of creep allowable in the particular design – in this case 0.1% in 200 hr. Theoretically, the limiting curve of 0.1% creep would be the form shown by FB, and this has been approximately confirmed for a mild steel at 400° C. In the absence of experimental information, it is safest to assume that the 0.1% creep line lies along FA.

Although increase in cyclic speed results in a higher stress for a given fatigue endurance, there is evidence that, at a given stress, increase in cyclic speed results in shorter life in terms of time. A safe assumption is that time-to-fracture is reduced in an inverse ratio to the increase in speed. (It is very probable that this ratio is decidedly over-cautious.) Thus, if an increase in speed from the laboratory test speed of 2000 cycles per min. to the 60,000 cycles per min. for turbine blades shortens the fatigue life in the inverse ratio,

(Continued on p. 180)

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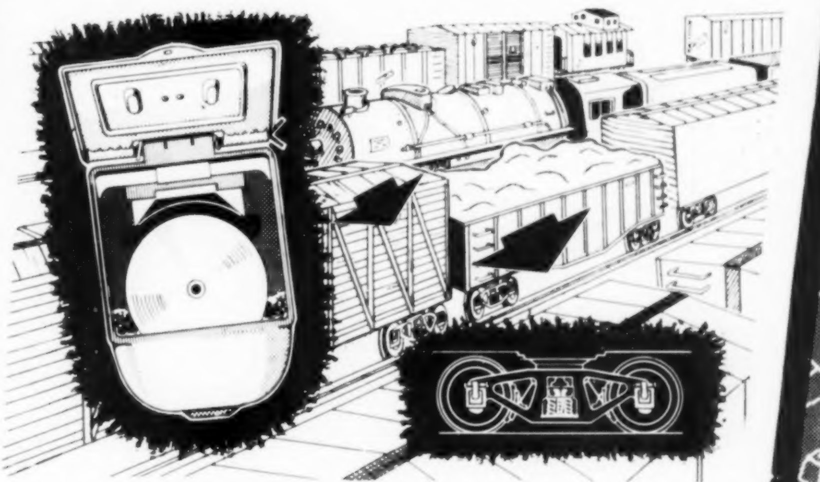

Performance of railroad journal bearings, under heavy load applications at relatively low speeds, can not be anticipated by the usual physical tests of tensile strength, elongation, etc. Since it is impossible to maintain a perfect oil film between the rotating journal and bearing, the behavior of bearing metals under momentary *metal-to-metal* contact becomes a major distinguishing characteristic.

With proper shaft alignment and reliable lubrication, bronze alloys are among the highest in fatigue strength and load carrying capacity.

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High-Temperature Fatigue

(*Continued from p. 178*)

then the stress to give failure in 200 hr. at 60,000 cycles per min. would be the same as that to give failure in 6000 hr. at 2000 cycles per min. Thus, in Fig. 2 a lower curve than ABCDE (2000 cycles per min.) has been shown at GHE representing 60,000 cycles per min.

The area OGHF then approximately represents the limiting stress conditions within which fatigue failure or creep exceeding 0.1% will be avoided. A third dimension or coordinate may be added to make the figure cover a range of times.

In 1942 some additional fatigue tests were made wherein it was shown: (*a*) That neither R.ex 78 nor Nimonic 80 showed any appreciable loss in strength at 650° C. (1200° F.) when subjected to exhaust gases from a combustion chamber burning kerosene; however, alloys used for blades may suffer reduction in both fatigue and creep strength from ash deposit from the burning of residual oils containing V_2O_5; (*b*) specimens of R.ex 78 and Nimonic 80 of rectangular section with small fillet radii of 0.015, 0.025 and 0.040 in. loaded with fluctuating stresses at 650° C. suffered some reduction in endurance; and (*c*) on the basis of fatigue testing at 650° C., satisfactory welds could be made between Nimonic 80 and Stayblade or Nimonic 75, and between R.ex 78 and Stayblade.

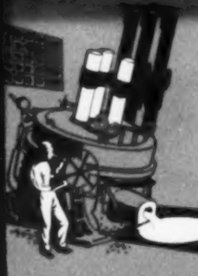
G. M. Ault

Hot Workability of White Cast Iron*

White cast iron, because of the presence of free cementite, is very hard and therefore difficult to machine. For this reason, the direct use of this material is limited to specialty products, such as chill cast rolls, rolling stock wheels, and the like. However, since it contains a relatively high percentage of austenite at temperatures above Ar_1, cast iron should possess a fair amount of plasticity when hot, and be amenable to forging or pressing. Fur-

(*Continued on p. 182*)

*Digest of "Plastic Forming of White Iron Castings", by G. I. Pogodin-Alexeyev, *Vestnik Mashinostroyenya*, Vol. 31, April 1951, p. 57.



Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

Door knobs are blanked and drawn from 0.035 in. steel or brass on this Lehigh H progressive die. Before Lehigh H was used, the die was redressed almost daily. Now, in addition to providing a better surface on the knobs, the die requires redressing only every sixth week.

This progressive 7-stage die, made entirely of Lehigh H, is used to blank, emboss and form parts for venetian blinds, using 0.032 in. cold rolled steel. The die is hardened to Rockwell C 61.

THREE HIGH-PRODUCTION DIES MADE OF LEHIGH H

Lehigh H is a high-carbon, high-chromium tool steel with characteristics that make it ideal for high-production dies for long-run jobs. Here are the reasons why toolmakers have used it over so many years, with excellent results:

1. Maximum Wear Resistance. Because of its high carbon-chromium content, Lehigh H puts up good resistance to wear. It is the most economical steel for long runs.

2. Close Tolerances. Lehigh H is an air-hardening steel, with only minimum distortion during heat-treatment.

3. Safe Hardening. It is cooled in still air from a hardening temperature of 1850 F, and minimizes the cracking hazards of intricate dies, thin sections, and insufficient radii.

4. Severe Service. Lehigh H is a deep-hardening steel, even in large sections, and has high compressive strength.

When three die rings were needed for high-production blanking of covers for large drums for shipping carbide, the manufacturer specified that each ring be held to close tolerances, and after hardening have a Rockwell C hardness of 61 to 63. The rings were made from Lehigh H. Each was given a C scale Rockwell test at four points, with these results: Ring 1: 61, 62, 61, 61; Ring 2: 62, 62, 63, 62; Ring 3: 63, 62, 61, 61.

Peeling Off Ribbons

This chip is curling off the tread of a 33 in. railroad car wheel. The tire-forming tool, nearly hidden at the left, is made of Bethlehem 66 High-Speed Steel, and is used for both roughing and finishing. On untreated wheels these tools average about 45 wheels before regrinding is necessary; on heat treated wheels, they average 16 per grind.

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In operations such as punching and blanking, the service life of the tool is largely dependent upon the tool clearance. For example, many punch-and-die sets are made up with a "standard" clearance. But as the proper clearance for punching soft steel is approximately one-tenth of the stock thickness, it is evident that the "standard" clearances are correct for only one stock thickness.

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Hot Workability of White Cast Iron

(Continued from p. 180)

thermore, plastic deformation may accelerate graphitization, thereby reducing the time required for obtaining malleable iron products.

Various experiments were carried out under both laboratory and works conditions to verify these suppositions. The iron used contained 2.23% C, 0.52% Mn, 1.39% Si, 0.122% P, and 0.034% S, and had a hardness of 400 Brinell. The strongly dendritic structure consisted of cementite in a pearlite matrix, and there was no indication of free graphite.

A series of preliminary tests was carried out to establish the best heating schedule for subsequent working. For this purpose a number of cylindrical specimens 0.4 in. diameter were heated for 10 to 60 min. at various temperatures between 1290 and 1740° F., and either allowed to cool in air or quenched in water. It was found that heating for only 1 hr. at 1560° F. or 10 min. at 1740° F., caused the formation of isolated graphite globules, and it was concluded that preheating for 10 to 15 min. at 1650 to 1740° F. is most convenient for the purpose. Unless otherwise stated, such treatment was applied throughout the experiments.

Upsetting tests were performed on cylinders 1.4 in. diameter and 1.6 in. long in the as-cast condition. These could be reduced without any trouble to 1/3 of the original length by employing light blows of a 500-lb. pneumatic hammer. They also withstood compression of 75% without developing cracks.

Microscopic examination of the upset specimens showed a considerable proportion of graphite, which exceeded many times the minute quantities found after heating to the forging temperature only (without subsequent plastic deformation). Moreover, the amount of graphite in the microstructure increased with increasing plastic strain suffered by the metal. The distribution of the newly formed graphite and its form were not uniform; at the periphery of the forged samples it appeared in the form of small "dots" and fine platelets while in the center as fairly large, irregular areas. Also, the orig-

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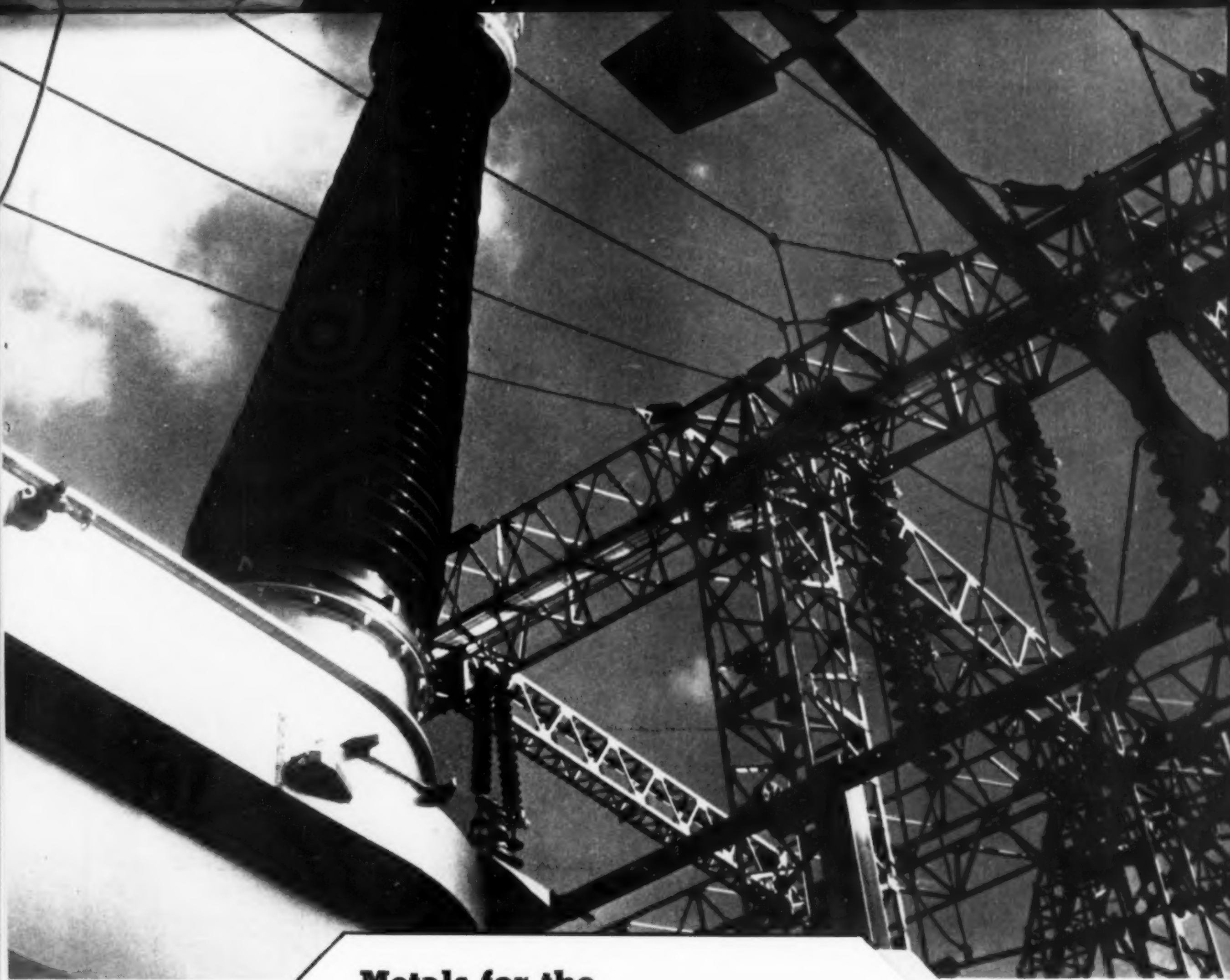

Hot Workability of White Cast Iron

(Continued from p. 182)

inal dendritic structure became fainter or even vanished entirely in some places. It was found, too, that annealing at 1740° F. produced a malleable iron structure (pearlite plus graphite) in the forged specimens in less than half the time required for the as-cast material.

Attention is called to the fact that the upper margin for the forging temperature is narrow, and that the impact energy of the individual blows of the hammer must be low. When an attempt was made to upset a cylinder with one or two heavy blows, extensive cracking resulted. A similar behavior, in spite of careful hammering, was noted when the cylinder was preheated to 1830° F. Cast bars can be forged down to reduce their cross section if these limitations are kept in mind.

Apart from the experiments described above, various other forming operations were successfully performed. For instance, cast flats of 0.6x0.24-in. section and about 3 in. long could be bent in a vise under 90° or twisted over 360° into a spiral without cracking. But when similar operations were attempted on samples preheated to 1795 to 1830° F., the specimens fractured immediately in a brittle manner without any prior plastic deformation. The author suggests that this behavior may be due to the presence of minute quantities of low melting point eutectics coupled with intensive graphitization during forging at high temperatures.

Finally, flat prismatic specimens from several casts were heated to different temperatures between 1435 and 1650° F. and then quenched into a bath of molten $NaNO_3$-KNO_3 (435 to 455° F.). After a brief immersion in the isothermal bath, the samples could be bent or twisted in the same manner as the samples receiving treatment at 1650 to 1740° F. The plasticity decreased, of course, as the austenite-to-martensite transformation progressed until the metal became completely brittle.

These results indicate that there may be a possibility of replacing casting by forging or pressing in the manufacture of certain malleable

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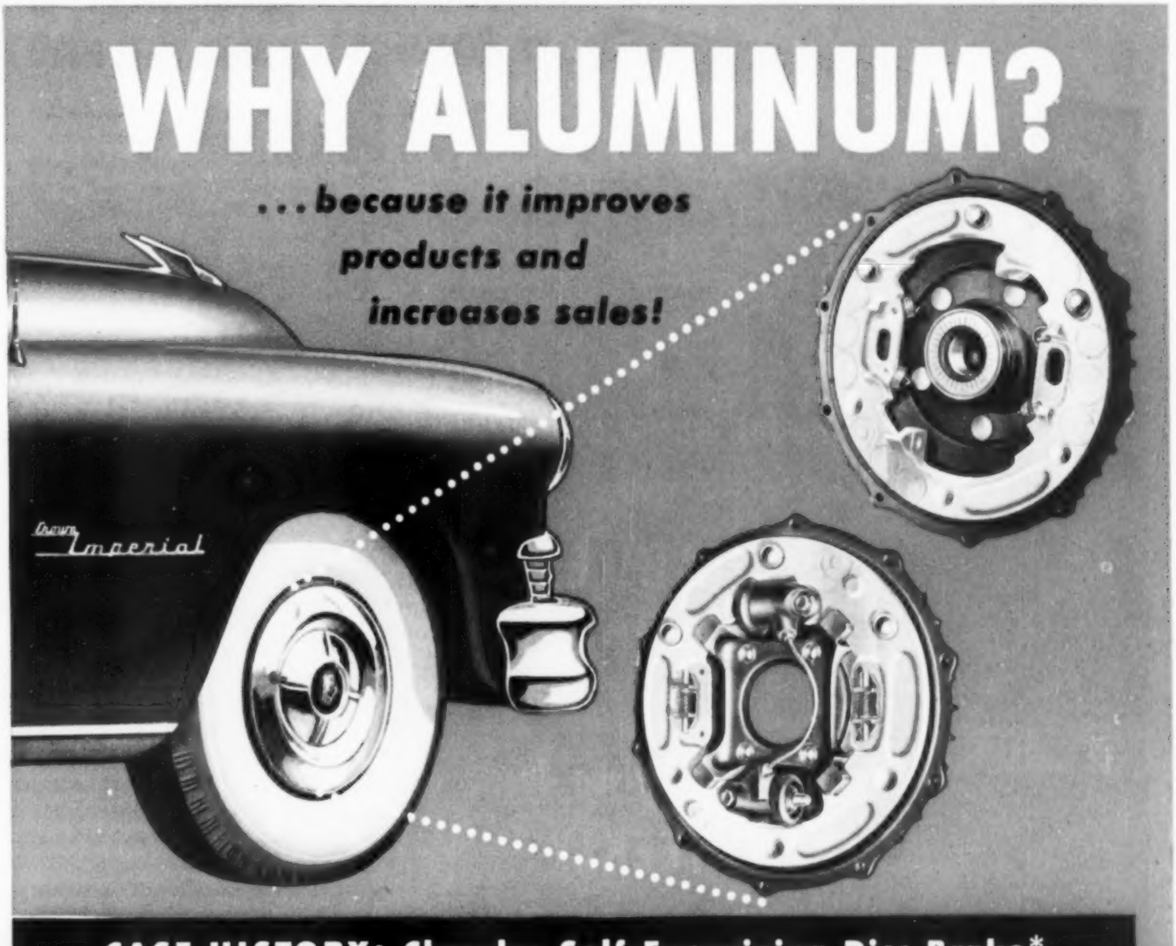

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Hot Workability of White Cast Iron

(*Continued from p. 184*)

iron products. In that way one could produce malleable parts of more difficult forms and to closer dimensional tolerances than casting permits. Also, the annealing period for mechanically worked products would be much shorter than for those cast only.

N. H. POLAKOWSKI

Effects of Alloying on Strain Aging of Rimming Steels*

THIS investigation was undertaken to determine the effect of vanadium or chromium additions on the strain aging of rimming steels. Previous investigators have claimed that the addition of 0.03 to 0.15% vanadium or of 0.30% chromium produces a high resistance to strain aging without affecting the rimming properties of the steel. The experimental procedure consisted of: *(a)* selecting a suitable test to measure resistance to strain aging; *(b)* determining the effect of vanadium additions by studying the resistance to strain aging in specimens prepared from laboratory, 10-ton openhearth, and 8-ton bessemer heats of rimming steels in which the vanadium varied from 0 to 0.16%; and *(c)* determining the effect of chromium by studying the strain aging in specimens prepared from a series of laboratory heats in which the chromium was varied from 0 to 0.44%.

The tensile test was selected to measure resistance of the various steels to strain aging. It was concluded from an analysis of the tensile data obtained from bright annealed sheets of an openhearth and a bessemer steel that the rate and extent of strain aging are reflected in data obtained from tensile specimens which have been strained in a tensile machine to 7½% elongation, aged at 212° F. for various times up to 24 hr., and loaded in the tensile ma-

(*Continued on p. 188*)

*Digest of "Effects of Vanadium or Chromium on the Strain Aging of Rimming Steels", by W. R. Jones and G. Coombes, *Journal* of the Iron and Steel Institute, Volume 174, May 1953, p. 9-15.

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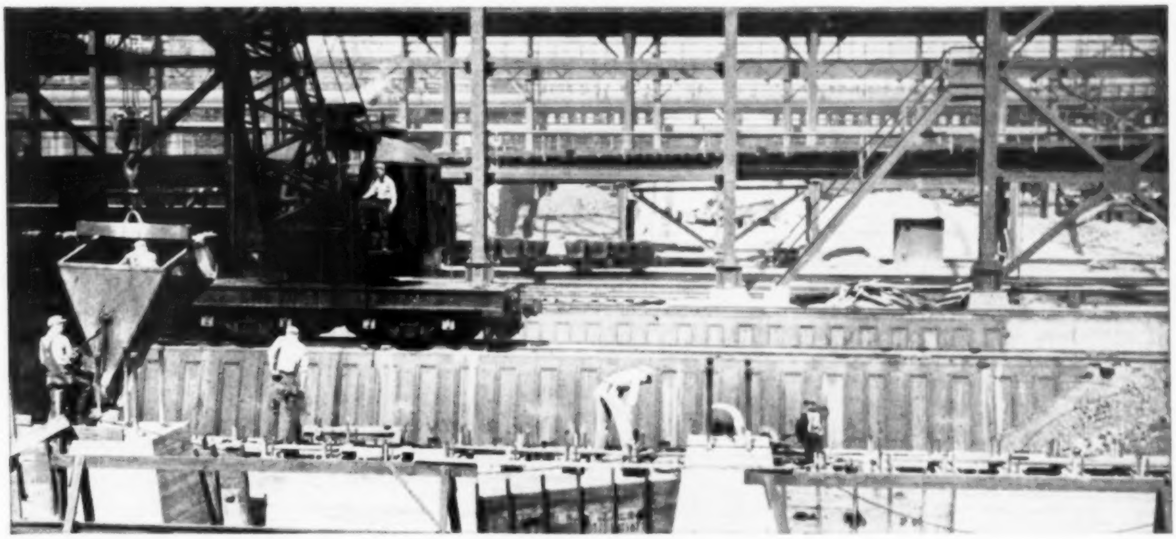

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Effects of Alloying on Strain Aging of Rimming Steels

(Continued from p. 186)

chine to failure. It was considered that steels which showed no increase in yield strength after straining and aging in this manner would not strain age at room temperature. In those steels which did strain age, the resistance to aging was measured by plotting the fractional increase in the yield as a function of the log of the aging time at 212° F. The aging time which corresponded to the midpoint in the increase in fractional yield from zero to maximum was used as the index of the steel's resistance to aging.

A series of 16-lb. laboratory heats of vanadium-bearing rimming steels was melted in an induction furnace and teemed into cast iron molds for round bars. These heats contained 0.13% C, 0.30% Mn, and 0 to 0.25% V. Vanadium up to 0.10% had no appreciable effect on the rimming action. These bars were forged and rolled into 20-SWG hard strip. After bright annealing at 1256° F. for 20 hr., tensile specimens were cut in the direction of rolling and tested for strain aging. It was found that vanadium additions in quantities greater than 0.02% produced essentially a nonaging steel.

Following the laboratory experiments, four 10-ton ingots of openhearth and one 8-ton ingot of bessemer vanadium-treated rimming steels were made. The analyses of these heats ran 0.07% C, 0.36% Mn, and 0 to 0.105% V. It was noted that the bessemer ingot (containing 0.05% V), and the two higher vanadium openhearth ingots (0.09 and 0.105% V) did not rim satisfactorily. The ingots were hot rolled, coiled at 1470° F., pickled, cold reduced to 20-SWG, sheared, and bright annealed at 1256° F. for 20 hr. Tensile specimens were prepared from the sheets and tested for resistance to strain aging. From these tests it was concluded that in a typical openhearth rimming steel the minimum amount of vanadium required to eliminate strain aging is 0.03%. This amount does not affect the rimming seriously. The vanadium addition did not appear to increase the

(Continued on p. 190)

Effects of Alloying on Strain Aging of Rimming Steels

(Continued from p. 188)
resistance to strain aging in the bessemer steel.

A series of laboratory heats of chromium-bearing rimming steel was prepared in the same manner as the vanadium-bearing heats. The resistance to strain aging was measured from tensile specimens prepared from these heats. It was found that chromium additions up to 0.45% were not completely effective in eliminating strain aging at 212° F. Additions up to 0.2% did not greatly affect rimming action.

The strain aging behavior of the vanadium steels can be qualitatively correlated with the equilibrium between nitrogen, vanadium, and vanadium nitride in the steel. Those steels to which sufficient vanadium had theoretically been added to combine with all of the nitrogen did not strain age, while those theoretically containing free nitrogen were susceptible to strain aging. In addition, it was possible to increase the susceptibility to strain aging in the vanadium steels by annealing at a temperature high enough (1292° F.) to dissociate vanadium nitride. Steels (such as bessemer) containing large amounts of nitrogen would require vanadium additions of such large quantity that the rimming action of the steel is likely to be seriously affected.

The dislocation theory is suggested as a possible mechanism for the action of vanadium on strain aging. Vanadium steels exhibit a pronounced yield point, and so the dislocations present must be anchored by "atmospheres" of the same nature as those believed to exist in plain carbon steels. These "atmospheres" contain nitrogen atoms, and the action of vanadium in eliminating strain aging must be due to preventing the nitrogen atoms in solution in the ferrite from diffusing through the lattice after plastic deformation. This is accomplished by the chemical combination of vanadium and nitrogen, and the "atmospheres" in vanadium rimmed steel must be composed essentially of vanadium nitride molecules.

F. X. Kayser

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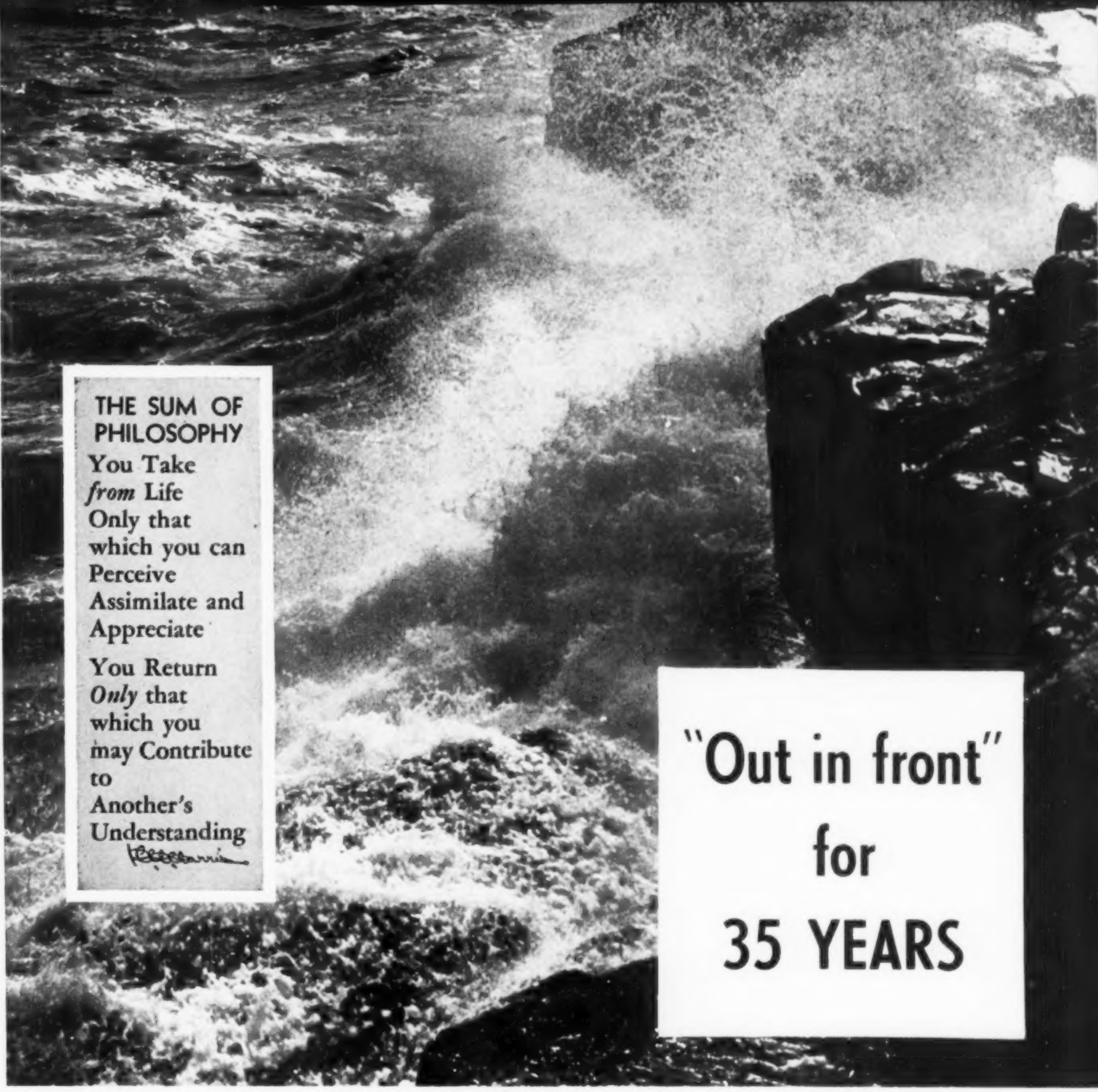

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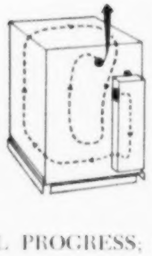

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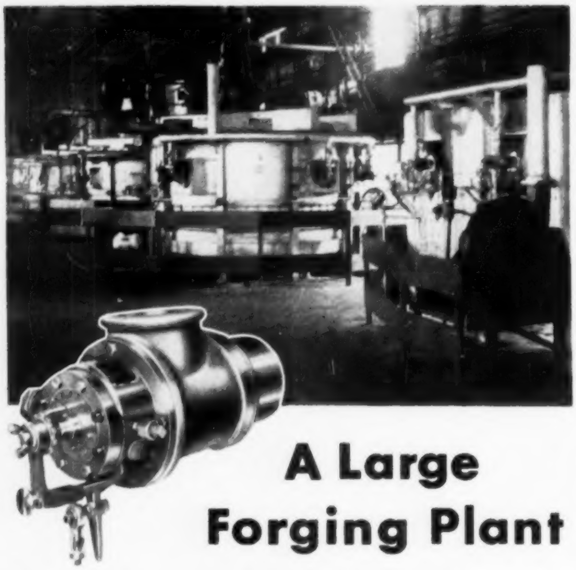

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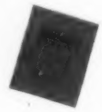

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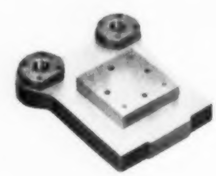

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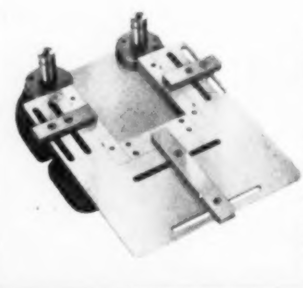

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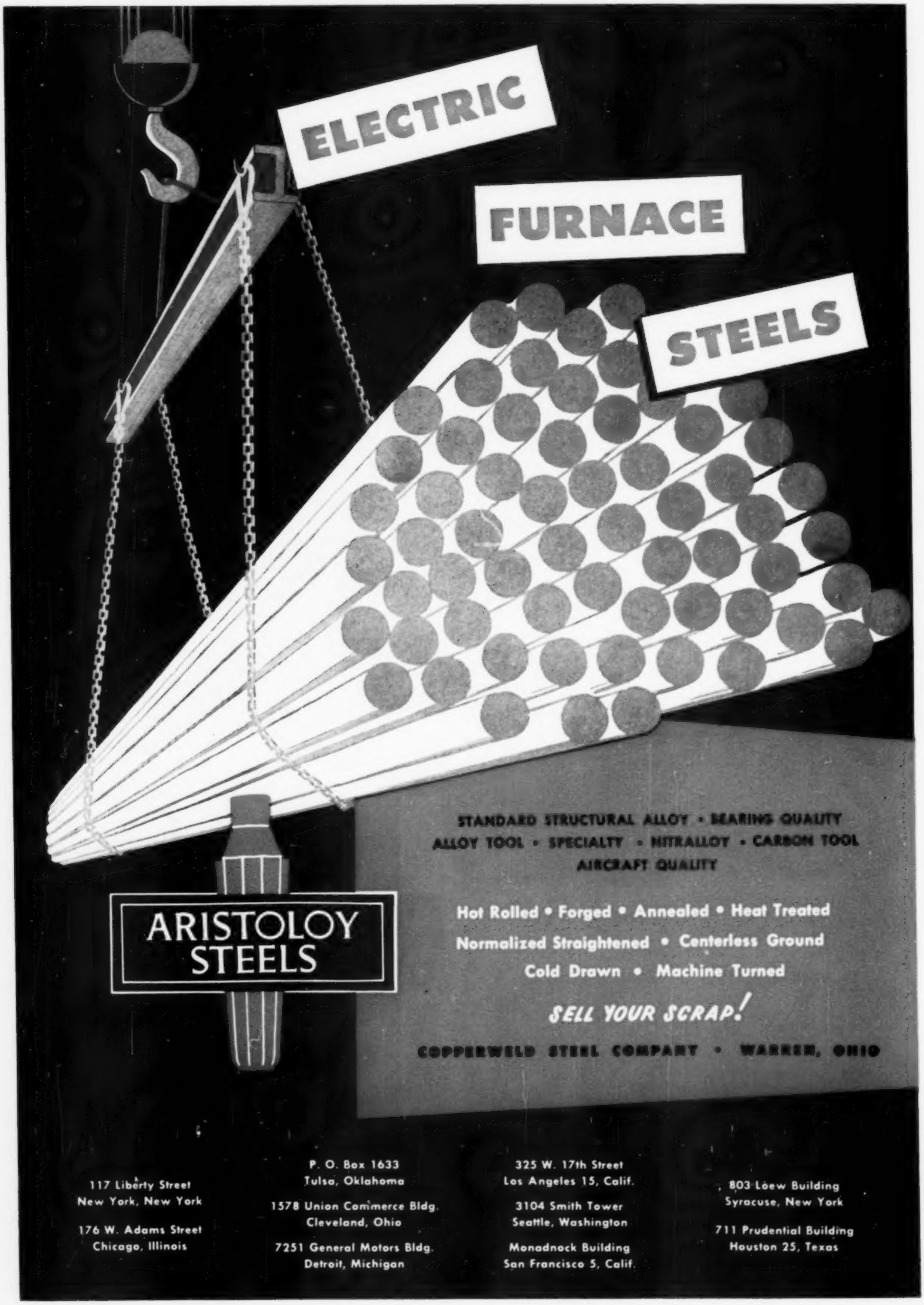
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